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# Centralized Trading, Transparency, and Interest Rate Swap Market Liquidity: Evidence from the Implementation of the Dodd–Frank Act

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## **Abstract**

We use proprietary transaction data on interest rate swaps to assess the effects of centralized trading, as mandated by Dodd–Frank, on market quality.

Contracts with the most extensive centralized trading see liquidity metrics improve by between 12% and 19% relative to those of a control group. This is driven by a clear increase in competition between dealers, particularly in U.S. markets. Additionally, centralized trading has caused interdealer trading in EUR swap markets to migrate from the United States to Europe. This is consistent with swap dealers attempting to avoid being captured by the trade mandate in order to maintain market power.

*Keywords:* Interest Rate Swaps; Pre-trade Transparency; Market Power; Liquidity; Swap Execution Facilities

*JEL Classification:* G10, G12, G14.

# I. Introduction

A key regulatory response to the 2008 Global Financial Crisis has been to improve the resilience and transparency of over-the-counter (OTC) markets for derivative contracts. To this end, over the last decade these markets have seen the introduction of clearing and margining and also increases in pre- and post-trade transparency, via centralized trading requirements and the creation of repositories containing information on completed trades.

This study focusses on a particular aspect of this regulatory change, an increase in pre-trade transparency in OTC markets, and we investigate how this has affected the competitive structure and liquidity of interest rate swap (IRS) markets. The global swap market is by far the largest OTC derivatives market (see Bank for International Settlements (2016)), and this is the first study of the impact of post-crisis regulation on that market. Historically, global swap trading was decentralized and relatively opaque. However, a centralized trading requirement was introduced in the United States in 2014 via the “Dodd–Frank Act”, which required that *any* trade in a sufficiently liquid IRS contract involving a U.S. counterparty *must* take place on a swap execution facility (SEF). SEFs are multilateral trading venues, featuring open limit order book (LOB) and request for quote (RFQ) functionalities, allowing customers to solicit quotes from multiple dealers and/or an order book simultaneously. Thus, SEFs introduced pre-trade transparency to a previously dark market and reduced customers’ costs of searching for liquidity.

We show that the introduction of SEF trading had several important effects on IRS markets. First, the evidence in our paper points to improvements in liquidity for swaps that were subject to the SEF trading mandate. Relative to EUR mandated swaps (where

SEF trading is much less prevalent), all liquidity metrics for USD mandated swaps improve significantly. For example, price dispersion (used here as measure of liquidity) drops by 12%–19%, which translates to *daily* execution costs for end-investors in USD mandated swaps falling by about \$3–\$6 million relative to those in EUR mandated swaps. When comparing mandated with non-mandated USD swaps, the results are slightly weaker with the relative improvement between these two groups being significant for most but not all liquidity metrics. However, given that liquidity improves overall for all USD contracts (i.e., mandated and non-mandated ones), we argue that this is likely driven by spillover effects from mandated to non-mandated contracts.

Second, we show that this improvement in liquidity is linked to more intense competition between swap dealers. Following the introduction of the SEF trading mandate, the number of active swap traders rose and we show that active U.S. clients (i.e., those clients most strongly affected by the regulation) traded with a significantly larger number of dealers after the trade mandate.

Finally, we show that the introduction of centralized trading in the United States led to the global EUR swap market fragmenting geographically, as the percentage of average daily trading volume between U.S. and non-U.S. domiciled dealers in EUR swaps declined abruptly from 20% to 5%. This decline in trans-Atlantic volume for EUR contracts was entirely driven by swap dealers with trading desks in multiple locations shifting the bulk of their interdealer activity to their non-U.S. (primarily European) branches.<sup>1</sup> This is consistent with EUR swap dealers trying to retain market power by blocking access to the

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<sup>1</sup>For related press coverage, see also “Big U.S. Banks Make Swaps a Foreign Affair” in the Wall St. Journal (<http://www.wsj.com/articles/SB10001424052702304788404579520302570888332>).

interdealer market to potential entrants. This is because, by transferring activity outside of the scope of U.S. rules and avoiding SEF trading, dealers retain the ability to exclude specific counterparties, something that is not possible (or easy) under the trade mandate. No similar pattern exists for trades between dealers and clients or trades in USD swaps.<sup>2</sup>

Our analysis uses proprietary data from the London Clearing House (LCH), supplemented with public data from the Depository Trust & Clearing Corporation (DTCC), for the period between Jan. 2013 and Sept. 2014. SEF trading was introduced to the United States in October 2013 and SEF trading became mandatory for a set of contracts in February 2014. Thus, our data cover the trading activity in the Global IRS market for a reasonable period before and after the regulatory change. Both data sources contain standard information on swap transactions. The LCH data additionally contain counterparty information from which we can infer traders' geographic locations and whether a trader is a dealer or a client. The DTCC data on the other hand indicate whether a trade was executed on a SEF.

We estimate a difference-in-differences model to isolate the effects of the introduction of SEF trading on liquidity, activity and competition. The treatment group in our analysis is the set of USD swaps that were required to trade on a SEF after Feb. 2014. Our control group is either the EUR swaps that were mandated, but which are mostly traded by non-U.S. persons who are not captured by the SEF trading requirement, or the USD swaps that were not captured by the SEF trading mandate. We measure liquidity using various price dispersion measures based on the metric proposed by Jankowitsch,

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<sup>2</sup>The USD market is dominated by U.S. persons who are subject to the trade mandate and as such, migrating its entire interdealer segment outside the United States would likely be impractical.

Nashikkar and Subrahmanyam (2011), plus Amihud’s price impact measure (Amihud (2002)) and a bid–ask spread derived from swap quote data.

This difference-in-differences setup is not without issues. First, the allocation of swaps to the treatment group is not exogenous. SEFs determine which swaps to trade and do so on the basis of liquidity. Second, the control groups have some limitations. For example, if SEF trading affects the liquidity of a mandated USD swap there may be spillovers to non-mandated USD swaps that are nearby on the maturity curve. We discuss these issues further in Section IV and argue that they are unlikely to overturn our main results.

To place our analysis within the context of recent theory work on transparency, our result that centralized trading has improved liquidity and increased dealer competition for mandated swaps lends support to the research of Duffie, Gârleanu and Pedersen (2005) and Yin (2005). These authors argue that pre-trade quote transparency is a necessary condition for competitive liquidity provision and lower transaction costs for customers since it reduces search frictions. Foucault, Pagano and Röell (2013) argue that in the presence of positive search costs, a unique Nash equilibrium exists where dealers quote monopolist prices (i.e., prices that equal end-users’ reservation values). Thus, reducing search costs allows customers to access keener pricing.<sup>3</sup> Hendershott and Madhavan (2015) examine how electronic venues may facilitate trading in OTC markets. They show that periodic one-sided electronic auctions, similar to the RFQ mechanism we see on SEFs, encourage

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<sup>3</sup>Vayanos and Wang (2012) survey the literature and explain how illiquidity is related to various market imperfections. They show that participation costs, imperfect competition and search frictions all have a detrimental effect on liquidity.



dealer competition and result in better prices while limiting information leakage. Our results run counter to the intuition in de Frutos and Manzano (2002) and Foucault, Moinas and Theissen (2007). The former argue that risk-averse dealers price less keenly in transparent markets, since, to induce trades that correct an inventory imbalance, they only need to marginally improve the quote on the relevant side of the market relative to their competitors. Foucault et al. (2007) show that when informed trading intensities are low, lower transparency (in the form of hiding trader identity information) can lead to higher liquidity.

Empirical work on the link between transparency and liquidity contains mixed results. Boehmer, Saar and Yu (2005) show that liquidity of NYSE stocks increased significantly when the exchange began to publish the limit order book to traders not located on the exchange floor. Green, Hollifield and Schürhoff (2006) study municipal bond dealers. They argue that opacity in this market increases dealer market power and they show how market power increases execution costs. Goldstein, Hotchkiss and Sirri (2007), Edwards, Harris and Piwowar (2007), and Bessembinder, Maxwell and Venkataraman (2006) show that introducing post-trade transparency to U.S. corporate bond markets had, on balance, a positive effect on liquidity (with exceptions for thinly-traded bonds and for the largest trades).<sup>4</sup> In contrast, Foucault et al. (2007) show that imposing anonymity on trading activity, that is reducing transparency, increased liquidity in Euronext stock trading. Friederich and Payne (2014) find the same result in data from the London Stock Exchange, attributing it to the possibility of predatory trading under transparency (i.e.,

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<sup>4</sup>Other evidence that links transparency with liquidity can also found in Harris and Piwowar (2006) and Naik, Neuberger and Viswanathan (1999).

when identities are revealed). Our results chime with those that suggest a positive link between transparency and liquidity.<sup>5</sup>

Our work is also related to other recent studies focusing on regulatory developments in OTC derivative markets.<sup>6</sup> Loon and Zhong (2014) and Loon and Zhong (2016) study the effects of centralized clearing and post-trade reporting on CDS markets. Both of these reforms, mandated by Dodd–Frank, are shown to improve liquidity, while the former also reduces credit risk. Our focus is different, in that we study the impact of pre-trade transparency as related to the third pillar of the Dodd–Frank OTC derivatives regulation (i.e., the mandate for centralized trading) and we also examine the IRS market, which is much larger than the CDS market.<sup>7</sup>

Our result that EUR swap markets have fragmented due to the U.S. SEF trading mandate ties into a recent regulatory literature on the efficacy and impact of the reform (see Giancarlo (2015), Massad (2016), and Powell (2016)). The result suggests that there are costs, pecuniary or otherwise, to trading on SEFs that dealers wish to avoid. As mentioned earlier, one possibility is that dealers move activity from their U.S. desks to their European desks in order to retain control over who they deal with. This could allow them to exclude new entrants from the interdealer EUR swap market which, in turn, would

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<sup>5</sup>Our results are also in line with the experimental evidence in Flood, Huisman, Koedijk and Mahieu (1999).

<sup>6</sup>See Spatt (2017) and Acharya, Engle, Figlewski, Lynch and Subrahmanyam (2009) for an overview of the post-crisis derivatives reform agenda.

<sup>7</sup>It is worth noting that Loon and Zhong (2016) include a SEF dummy variable in their panel regressions but as their sample period ends before the introduction of the CFTC trading mandate, in February 2014, their study does not assess the impact of the trading mandate on liquidity.

preclude those new entrants from trading effectively in the client market.<sup>8</sup> Thus, the geographic fragmentation we observe is consistent with dealers attempting to maintain entry barriers to (EUR) swap trading.

Overall, our analysis highlights the importance of dealer market power in understanding how financial markets react to changes in transparency. This remains an area of policy interest. In Jan. 2018 Europe adopted new centralized trading rules for swaps as part of the Markets in Financial Instruments Regulation (MiFIR). This has the potential to improve conditions for customers and also to remove the imbalance in regulation that has led to the geographical fracture in swaps markets. At the same time, in the U.S., there is uncertainty as to whether all parts of the Dodd–Frank Act will be retained as law with the new CFTC trading rules being at the heart of this discussion among policy makers and practitioners.<sup>9</sup>

The rest of the paper is as follows. Section II sets out the regulatory changes that affected swap markets as a result of Dodd–Frank and gives a detailed description of SEFs. Section III describes our data sources and presents summary statistics. Section IV presents the difference-in-differences tests of the impact of the SEF trading mandate on market activity and liquidity. Section V shows how the mandate has changed the relationships between dealers and customers. It also describes the changes in the geography of swap trading and how those changes may be linked to market power. Section VI concludes.

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<sup>8</sup>This would not be feasible for USD swaps as the interdealer market is well established, geographically, in the U.S., while the bulk of EUR swap trading already happens in Europe.

<sup>9</sup>See, for example, related reporting by Bloomberg: <https://www.bloomberg.com/gadfly/articles/2017-02-23/wall-street-girds-for-regulatory-battles-loud-and-quiet>

## II. Policy Context and Institutional Details

### A. OTC Derivatives and the Dodd–Frank Act

A major pillar of the U.S. Wall Street Reform and Consumer Protection Act (the “Dodd–Frank Act”) concerns OTC derivatives markets. Owing to concerns that insufficient collateralization and opacity in these markets contributed to systemic risk during the crisis, the Act implemented reforms aimed at reducing counterparty risk and improving transparency in swaps markets. It mandates centralized clearing for eligible contracts, requires real-time reporting and public dissemination of transactions and also requires that eligible contracts should be traded on a SEF, a type of multilateral electronic trading venue. SEF trading markedly increases the level of *pre-trade* transparency for affected swap contracts.

The CFTC implemented the Dodd–Frank trading mandate in two phases. First, on Oct. 2, 2013, SEF trading became available for OTC derivatives on a voluntary basis. As of that date, newly authorized trading venues had to comply with a number of principles and requirements. One of these requirements was the obligation to operate a LOB.<sup>10</sup> Subsequently, specific contracts were explicitly required to be executed on SEFs. The

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<sup>10</sup>This does not mean that there were no electronic venues for swap trading before Oct. 2, 2013. It means that after this date, any venue that was officially recognized as a SEF had to comply with the specific CFTC minimum requirements mentioned above. Unfortunately, we have no data on swap trading prior to Oct. 2, 2013. Nevertheless, if swaps were already being traded on pre-trade transparent electronic platforms before this date, this should bias us against finding any differences in market conditions when making a “before versus after” comparison. Our analysis shows that the differences were actually substantial.

mandate captured IRS contracts of various currencies and maturities as well as several credit default swap (CDS) indices. The decision as to which swaps were to be SEF-traded was in the hands of the SEFs themselves, through the made available to trade (MAT) procedure. A SEF can submit a determination that a swap is available for trade to the CFTC, which then reviews the submission. Once a swap is certified as available to trade, all other SEFs that offer this swap for trading must do so in accordance with the requirements of the trade mandate. The criteria for MAT determination include the trading volume of the swap and the frequency of transactions. Table 1 shows the mandated maturities along with the mandate date for the plain vanilla USD- and EUR-denominated IRS contracts which we study. Most maturities were mandated on February 15, 2014 with a couple more following a few days later on the 26th.

### [TABLE 1]

The SEF trading mandate only captures “U.S. persons,” with that definition being relatively broad.<sup>11</sup> Importantly, the mandate affects the trades of U.S. persons regardless of who their counterparty is. In other words, if a U.S. person is to trade a mandated contract with a non-U.S. person, the trade has to be executed on a SEF.

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<sup>11</sup>Apart from U.S.-registered swap dealers and major participants, the definition of a U.S. person also includes foreign entities that carry guarantees from a U.S. person (e.g., the foreign branch of a U.S. dealer) and also any entities with personnel on U.S. soil which is substantially involved in arranging, negotiating or executing a transaction. According to market reports this created initially some uncertainty as to who is captured. See for example: <http://www.risk.net/risk-magazine/news/2256600/broader-us-person-definition-could-cause-clearing-avalanche-participants-warn>

## B. SEF Characteristics

SEFs are electronic trading platforms where, according to the CFTC, “multiple participants have the ability to execute swaps by accepting bids and offers made by multiple participants in the platform.” In practice, SEFs accomplish this using two different trading mechanisms. The first is a standard central limit order book. All SEFs must offer an order book and, theoretically, this functionality allows end-users to bypass dealers altogether in concluding a trade, assuming of course that the order book has sufficient liquidity.

The second functionality is a RFQ mechanism. While this operates similarly to pre-existing single-dealer RFQ platforms, the innovation is that a client’s request for a quote must be disseminated simultaneously and instantly to multiple dealers instead of just one. Thus, clients can easily compare prices across dealers and competition between dealers for client order flow intensifies. Until October 2014, the law required that a RFQ be communicated to at least two dealers and, subsequently, to no less than three. Having received a RFQ, dealers respond by posting their quotes to the client.<sup>12</sup> Importantly, dealers cannot see each others’ quotes nor do they know which other dealers have received the request. In addition, those responding to the RFQ cannot be affiliated with the RFQ requester and may not be affiliated with each other. This arrangement makes collusion between dealers difficult and effectively renders the bidding process a first-price, sealed bid auction.

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<sup>12</sup>It is worth noting that, due to concerns about information leakage of future trading intentions, the CFTC did not require that the identity of the RFQ requester be disclosed. See Foucault et al. (2007) and Nolte, Payne and Vasios (2015) for a discussion on the implications of the disclosure of counterparty IDs.

The two trading functionalities are designed to operate in conjunction for mandated swaps.<sup>13</sup> Practically, a SEF must provide a RFQ requester with any resting bid or offer on the order book alongside any quotes received by the dealers from whom quotes have been requested. The requester has the discretion to execute either against the LOB quotes or against the RFQ responses.<sup>14</sup> After a LOB or RFQ trade, the SEF can establish a short work-up session open to all market participants. During the work-up, market participants can trade an additional quantity of the same swap at the same price as the initial trade, with first priority in execution given to counterparties who initiated the first trade.<sup>15</sup>

Many SEFs trade the swaps that we study. Data from LCH for April to September 2014 show that for USD swaps the most active SEFs were Tradeweb (with a market share of 20.6%), ICAP (19.8%), Tullet Prebon (17.2%) and Bloomberg (15%). Total USD trading activity for this period was \$4,770bn. ICAP had the largest market share in EUR trading (at 34.8%), followed by BGC Partners (25.0%), Tullet Prebon (15.0%) and Tradeweb (10.6%). Total trading volume in the EUR contracts was €4,444bn. In both cases, no other SEF had a market share above 10%. Thus, some of the most active SEFs are operated by brokers, while others are run by specialist information and trading systems firms. We have no data on the fraction of SEF trading in IRS occurring on order books versus RFQ, but

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<sup>13</sup>Any trades of swap contracts that are not subject to the mandate can still be executed on a SEF and the SEF must offer an order book. However, the SEF is also free to offer any other method of execution (including bilateral trading and voice-based systems) for these trades.

<sup>14</sup>Collin-Dufresne, Junge and Trolle (2016) analyze SEF trading of index CDS and show that most dealer-to-customer trades are done via RFQ, while interdealer trades use several different execution mechanisms.

<sup>15</sup>Duffie and Zhu (2017) show that work-up protocols can enhance price discovery and liquidity.

Riggs, Onur, Reiffen and Zhu (2018) show that LOB usage is limited in SEF trading of index CDS.

Overall, SEFs change the microstructure of the market in two important ways. First, they increase pre-trade transparency by allowing market participants to observe prices quoted by dealers much more easily. Second, SEFs increase competition between swap liquidity suppliers. They make comparison of dealer quotes straightforward, they allow new entrants to start supplying liquidity on LOBs, and they allow end-users to trade directly with each other and to bypass dealers completely.

### **III. Data and Summary Statistics**

#### **A. Swap Transaction Data**

We use transaction data for USD and EUR denominated vanilla spot interest rate swaps, which we obtain from LCH and DTCC. LCH clears approximately 50% of the global interest rate swap market and more than 90% of cleared interest rate swaps through its SwapClear platform. Its services are used by all major dealers. We obtain reports of all new trades that were cleared by LCH between Jan. 1, 2013 and Sept. 15, 2014.

Each LCH report contains the trade date, effective date, maturity date, notional, swap rate, and other contract characteristics. It also includes counterparty identities, which allows us to categorize trades by type of counterparty (dealer vs. non-dealer) and location (U.S., EU etc). As is standard in this market, we classify the top 16 banks by volume in



our sample as dealers, while any other counterparty is classified as a client.<sup>16</sup> Since Apr. 2014 LCH reports also contain information on whether a transaction is executed on a trading venue, the name of the venue, as well as whether the venue is authorized as a SEF.

We apply a number of filters to clean the data. First, we remove duplicate reports, which arise because one report is generated for each side of a cleared trade. Then we keep only spot starting swaps, while removing portfolio and compression trades as they are not price-forming.<sup>17</sup> Finally, we filter inaccurate and false reports, defined as those where the percentage difference between the reported swap rate and Bloomberg’s end-of-day rate for the same currency and maturity is more than 5% in absolute value.

Although LCH is the global leader in IRS clearing, there are other clearing houses that offer competing services (e.g., the Chicago Mercantile Exchange (CME)). To ensure that our results are representative of the entire market, we complement the LCH data with data from DTCC, a trade repository (TR) operator. We extract all transactions that were reported to them between Jan. 1, 2013 and Sept. 15, 2014. We filter the DTCC data in a similar way to the LCH data and we remove any trades that were reported to both LCH and DTCC via an algorithm that matches LCH and DTCC reports based on contract characteristics that are common to both data sets.

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<sup>16</sup>This choice is not arbitrary as these 16 banks are classified as “Participating Dealers” in the OTC Derivatives Supervisors Group, chaired by the New York Fed:

[https://www.newyorkfed.org/markets/otc\\_derivatives\\_supervisors\\_group.html](https://www.newyorkfed.org/markets/otc_derivatives_supervisors_group.html)

<sup>17</sup>Compression trades are used in order to reduce the total notional amounts outstanding of participating institutions, while leaving their net notional amounts unchanged. The purpose of this is to manage counterparty exposures while maintaining the same level of exposure to market risk.

**[FIGURE 1]**

After filtering the data, we are left with a sample of 628,896 trade reports which account for a total \$58.17 trillion in notional. In Figure 1 we show the time series of trading volume by currency. This figure illustrates the sheer size of the swap market with volumes around \$70–\$80 billion for each currency on a daily basis. We can also see that total volume is roughly equally split between USD and EUR denominated swaps.

**[FIGURE 2]**

Graph A of Figure 2 displays volume shares by counterparty type. The majority of trades are interdealer, consistent with the commonly held view that a small group of dealers dominates the swap market. Dealer-to-client trades account for about one-third of volume in both currencies. One difference between currencies is that the share of client-to-client activity is twice as large for USD-denominated swaps than it is for EUR swaps.

With regard to location, we split trading activity into i) trades between U.S. financial institutions, ii) trades between U.S. and non-U.S. financial institutions, and iii) trades between non-U.S. financial institutions. Graph B of Figure 2 presents these data. About 50% of trading in USD-denominated swaps involves a U.S. and a non-U.S. counterparty, 30% two U.S. counterparties, and 20% two non-U.S. counterparties. For EUR-denominated swaps, U.S. to non-U.S. trading activity is only 14% of the sample, with the vast majority of trades, about 80%, between non-U.S. counterparties. This means that the SEF trading mandate has little bite in EUR swap markets, as they are dominated by non-U.S. counterparties. This observation motivates part of our empirical strategy.

## IV. SEF Trading and Market Quality

### A. Liquidity Variables

We measure liquidity with five metrics that are built from transaction data or intraday bid–ask quotes provided by Thomson Reuters. One limitation of the trade reports is that they are not time-stamped and so we cannot construct metrics that rely on transaction sequencing. Instead, we mainly use metrics that only require executed trades and bid–ask quotes.

Our first three liquidity metrics are based on price dispersion. These measures are estimates of the relative effective spread and as such we use them to measure execution costs. The first is that proposed by Jankowitsch et al. (2011):

$$(1) \quad \text{DISP\_JNS}_{i,t} = \sqrt{\sum_{k=1}^{N_{i,t}} \frac{\text{VLM}_{k,i,t}}{\text{VLM}_{i,t}} \left( \frac{P_{k,i,t} - m_{i,t}}{m_{i,t}} \right)^2},$$

where  $N_{i,t}$  is the number of trades executed for contract  $i$  on day  $t$ ,  $m_{i,t}$  is Bloomberg’s end-of-day  $t$  mid-quote for contract  $i$ ,  $P_{k,i,t}$  is the execution price of transaction  $k$ ,  $\text{VLM}_{k,i,t}$  is the volume of transaction  $k$  and  $\text{VLM}_{i,t} = \sum_k \text{VLM}_{k,i,t}$  is the total volume for contract  $i$  on day  $t$ . Jankowitsch et al. (2011) derive this measure from a microstructure model where it is shown to capture inventory and search costs. Low price dispersion around the benchmark indicates low trading costs and high liquidity, and vice versa.

A variant of the Jankowitsch et al. (2011) measure uses the average execution price on a day as the price benchmark instead of the end-of-day midquote. This should improve

the performance of the measure on days of high intraday volatility:

$$(2) \quad \text{DISP\_VW}_{i,t} = \sqrt{\sum_{k=1}^{N_{i,t}} \frac{\text{VLM}_{k,i,t}}{\text{VLM}_{i,t}} \left( \frac{P_{k,i,t} - \bar{P}_{i,t}}{\bar{P}_{i,t}} \right)^2} ,$$

where notation is as above and  $\bar{P}_{i,t}$  is the average execution price on contract  $i$  and day  $t$ .

We require at least four intraday observations to determine the average execution price.

As estimates of the effective spread, both of the above dispersion metrics are potentially biased due to intraday volatility. Note that although the second dispersion metric reduces the intraday volatility bias, it does not eliminate it since the same average execution price can be obtained from both extremely volatile and relatively stable intraday paths for the mid-quote. Thus, we also employ the spread estimator proposed in Benos and Žikeš (2018) which, subject to weak assumptions about prices, is bias-free.<sup>18</sup> The estimator is equal to:

$$(3) \quad \text{DISP\_BZ}_{i,t} = \sqrt{\max\{2(3\text{DISP\_EW}_{i,t}^2 - \text{DISP\_JNS\_EW}_{i,t}^2), 0\}} ,$$

where  $\text{DISP\_EW}$  and  $\text{DISP\_JNS\_EW}$  are given by the formulas for the previous dispersion metrics but where  $\text{VLM}_{k,i,t}/\text{VLM}_{i,t}$  is replaced by  $1/N_{i,t}$ . Note that all dispersion metrics are comparable across contracts with different base currencies and maturities as they are percentage deviations from a price benchmark.

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<sup>18</sup>Žikeš (2017) explores the asymptotic properties of this estimator.

Our fourth liquidity measure is the Amihud (2002) price impact measure:

$$(4) \quad \text{AMIHU}_{i,t} = \frac{|R_{i,t}|}{\text{VLM}_{i,t}} \quad ,$$

where  $R_{i,t}$  is the price change for contract  $i$  on day  $t$  and  $\text{VLM}_{i,t}$  is the total volume expressed in \$ trillions. All of these liquidity measures have been used before in analysis of OTC derivatives markets and are shown to relate strongly to conventional liquidity proxies. See for example the evidence in Goyenko, Holden and Trzcinka (2009), Friewald, Jankowitsch and Subrahmanyam (2012), Friewald, Jankowitsch and Subrahmanyam (2017), Loon and Zhong (2014), Loon and Zhong (2016) and Benos and Žikeš (2018).

Finally, we also measure liquidity with the relative quoted spread based on intraday data obtained from Thomson Reuters. Bid and ask quotes for each contract are sampled every 10 minutes across the trading day and, assuming  $N$  intervals in a day, we calculate the daily average quoted spread for contract  $i$  on day  $t$  as:

$$(5) \quad \text{QSPREAD}_{i,t} = \frac{1}{N} \sum_{k=1}^N \frac{2(\text{ASK}_{k,i,t} - \text{BID}_{k,i,t})}{\text{ASK}_{k,i,t} + \text{BID}_{k,i,t}} \quad .$$

This liquidity measure is included to ensure robustness since it is not dependent on execution prices, which are used for all other liquidity metrics.

## B. Panel Difference-in-Differences Specifications

To assess the impact of SEF trading on market liquidity and activity, we estimate two panel difference-in-differences models. We wish to see if the introduction of SEF

trading for a treatment group of contracts causes their liquidity to diverge from that of a control group. SEFs were officially authorized by the CFTC (and trades could be executed on them on a voluntary basis) on Oct. 2, 2013 and the dates on which it became mandatory for U.S. persons to trade particular contracts on SEFs are shown in Table 1.<sup>19</sup> Table 2 summarizes the main variables used in our models.

## [TABLE 2]

Before presenting the results of our estimations, it is worth noting that a problem with our simple difference-in-differences approach is that the set of contracts mandated for SEF trading is not exogenous. In fact, as detailed in Section II, SEFs themselves determine which contracts they trade through the MAT procedure. Then, if the set of contracts made available to trade are precisely those that are most likely to benefit (in liquidity terms) from SEF trading, any evidence of liquidity improvement that we obtain will be a biased estimate of the true liquidity benefit associated with SEF trading. However, while it is clear that contracts made available for trade by SEFs were already the most liquid, this is not the same as saying that they chose contracts that were most likely to benefit in liquidity terms from SEF trading. Thus, while it is worth acknowledging there has been selection on average liquidity in this setting, we suspect that any bias might not be too severe.

Another possible concern with our difference-in-differences framework is that, if SEF trading causes liquidity to rise for mandated swaps, this improvement might spill over to

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<sup>19</sup>These event dates are well after the implementation of the trade reporting mandate on Dec. 31, 2012 and the clearing mandate on Mar. 11, 2013. The clearing mandate implementation date occurs during our pre-event sample period, but excluding data prior to this date does not change our results in any important way.

non-mandated swaps. For example, if dealers quote tighter spreads for the mandated 10Y USD swap, this may lead to tighter spreads in the (non-mandated) 9Y USD swap. If anything, though, this should create a bias towards us finding no significant effects and, in addition, it is a problem that should not contaminate the comparison of USD and EUR swaps.

### **Test 1: USD vs. EUR Mandated Contracts**

For our first difference-in-differences test we use the mandated USD-denominated contracts as a treatment group and mandated EUR-denominated contracts as a control group. The USD segment of the IRS market has a very high proportion of U.S. participants who are captured by the CFTC mandate, while the EUR contracts may be mandated but, as we saw earlier in the lower panel in Figure 2, are mainly traded by non-U.S. persons who are not required to trade on a SEF. Thus, if transparency improves liquidity, we would expect the liquidity of USD contracts to improve relative to that of EUR contracts.<sup>20</sup> An advantage of using the mandated EUR contracts as a control group is that the treatment and control groups have similar liquidity profiles, which implies that our results are not subject to the selection bias mentioned above. On the other hand, liquidity and activity in the EUR segment of the market might be driven by different fundamentals. We control for this by including a number of contract and currency specific control variables in our

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<sup>20</sup>Of course, to the extent that SEFs are also used by those trading in EUR mandated contracts, albeit to a lower degree, we might expect (small) improvements in their liquidity too.

specifications. We implement this test by estimating the following panel specification:

$$(6) \quad L_{it} = \alpha_i + \beta_1 \text{DATE}_t^{(1)} + \beta_2 \text{CURR}_i \times \text{DATE}_t^{(1)} + \beta_3 \text{DATE}_t^{(2)} + \beta_4 \text{CURR}_i \times \text{DATE}_t^{(2)} \\ + \gamma \text{SWAP\_RV}_{it} + \delta' X_t + \epsilon_{it} ,$$

where  $i$  indexes the set of swap contracts (defined by maturity and currency) such that the  $\alpha_i$  are contract-specific fixed effects and  $t$  denotes days.  $L_{it}$  is a liquidity or market activity variable. The liquidity variables are defined in equations (1) to (5) while our activity variables include daily volume traded, the daily number of trades and the number of unique market participants active on a day.  $\text{DATE}_t^{(j)}$ ,  $j = 1, 2$  are dummies for the SEF authorization and SEF mandate dates, respectively, equalling one after the event and zero otherwise.  $\text{CURR}_i$  is a dummy equal to one for USD contracts and zero for EUR contracts.  $\text{SWAP\_RV}$  is the daily contract-specific realized variance, calculated using 10 minutely quotes from Thomson Reuters.<sup>21</sup> It is included to make sure that our results are not driven by any differences in the volatility of the EUR- and USD-denominated contracts.  $X_t$  is a vector of currency-specific control variables intended to capture differences in fundamentals between the USD and EUR market segments, including stock market returns, stock index implied volatilities (as proxies for market uncertainty), overnight unsecured borrowing rate spreads for both markets (as proxies for dealer funding costs) and yield curve slopes. Our specification explicitly disentangles liquidity/activity in the two currency groups as well as any changes in liquidity after the two events. The coefficients  $\beta_1$  and  $\beta_3$  capture any effects that are common to both market segments and coefficients  $\beta_2$  and  $\beta_4$  capture incremental

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<sup>21</sup>The realized variance is smoothed by taking a 30-day rolling average of the daily variances.



effects that are particular to the USD segment. We cluster the standard errors by both maturity and currency.

### [FIGURE 3]

The left-column of plots in Figure 3 displays time-series of cross-swap mean values of our key dependent variables, separately for the EUR MAT and USD MAT samples, in the window prior to the SEF mandate date. These are displayed to shed light on the ‘parallel trends’ assumption that underlies our difference-in-differences analysis. The assumption appears to be a reasonable one for these data as the liquidity variables all evolve in rather similar fashion in the period of time before the SEF trading mandate came into force.

### [TABLE 3]

Tables 3 and 4 show the results of these estimations for the liquidity and activity variables respectively. The models are estimated with and without the control variables. Table 3 shows that after SEF trading became available on Oct. 2, 2013 there is an improvement in liquidity for both market segments as the significantly negative coefficients on DATE<sup>(1)</sup> and the insignificant interaction terms indicate. The only exception to this is for the quoted spreads, where a small but significant reduction in liquidity for USD contracts can be seen. Following the enforcement of the SEF trading mandate there is a clear differential effect between the USD and EUR segments of the market with the USD contracts showing a significant further liquidity improvement relative to the EUR contracts. This improvement is visible across all liquidity measures, with 11 of the 12 interaction terms being significantly negative at a 5% level and the other coefficient

significantly negative at 10%. Also, for USD quoted spreads, the second event date interaction is negative and much larger in magnitude than the positive interaction on the first event date, implying that overall USD quoted spreads fall relative to EUR spreads.

**[TABLE 4]**

The results in Table 4 suggest that there was a reduction in activity for EUR contracts and a respective increase in USD contracts mainly after the first event date (i.e., when SEF trading became available). It is interesting to note that, while activity in EUR mandated contracts declined, liquidity actually improved, as the market became more transparent. We do not observe any significant difference in trading activity between the USD and EUR contracts after the second event (Feb. 2014). Another noteworthy effect is that after both events, the number of parties trading in USD markets rose significantly relative to the number of traders in EUR markets. Thus, participation in USD markets grew.

In the activity and liquidity regressions, there are few consistently signed and consistently significant control variables. The realized volatility variable is always positive in the liquidity regressions (and is significant in half of the specifications). The VIX and VDAX are also often positive and significant (except in the quoted spread regressions) in the liquidity regressions. In the activity regressions, the control variables are only occasionally significant.

## Test 2: USD Mandated vs. USD Non-mandated Contracts

For the second difference-in-differences test we concentrate exclusively on USD contracts and use the mandated maturities as a treatment group and non-mandated USD swaps as the control group.<sup>22</sup> This test has the advantage of looking at contracts whose prices are driven by the same fundamentals and also cleanly compares mandated versus non-mandated contracts. We estimate the following panel regression:

$$(7) \quad L_{it} = \alpha_i + \beta_1 \text{DATE}_t^{(1)} + \beta_2 \text{MAT}_i \times \text{DATE}_t^{(1)} + \beta_3 \text{DATE}_t^{(2)} + \beta_4 \text{MAT}_i \times \text{DATE}_t^{(2)} \\ + \gamma \text{SWAP\_RV}_{it} + \delta' X_t + \epsilon_{it} ,$$

where now  $i$  denotes maturities and  $t$  denotes days. The  $\alpha_i$  terms are again contract-specific fixed effects. The key right-hand side variables used are the same as before with the only difference being that we now have a dummy variable ( $\text{MAT}_i$ ) indicating whether a given contract maturity has been mandated by the CFTC.

The right-column of plots in Figure 3 gives our ‘parallel trends’ analysis for the USD MAT versus non-MAT samples. Again, there is evidence that the dispersion measures are neither diverging nor converging across the two samples. For the quoted spread data, there is a small level shift in MAT spreads roughly 4 months before the first event date, which is gradually eroded as we approach the mandate event date. For the Amihud measure, the trend in USD non-MAT contracts is rather noisy although there is no sign of

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<sup>22</sup>The mandated maturities are: 2Y, 3Y, 4Y, 5Y, 6Y, 7Y, 10Y, 12Y, 15Y, 20Y and 30Y. The non-mandated maturities are: 1Y, 8Y, 9Y and 25Y.

divergence (or convergence) with that of USD MAT contracts. For this reason, we are inclined to place less weight on the difference-in-differences results from this variable.

### [TABLE 5]

Tables 5 and 6 show the results of these estimations for the liquidity and activity variables and for specifications with and without controls. There is evidence of liquidity improvement for both mandated and non-mandated contracts after SEF trading became available on Oct. 2, 2013. This is particularly clear in the dispersion metrics, but not for the Amihud measures or the quoted spread data. Focussing on the dispersion-based liquidity measures, after the second event date the liquidity of the mandated contracts tends to increase again while, if anything, that of non-mandated contracts deteriorates slightly. The picture is less clear for quoted spreads and the Amihud measure. On the second event date, the coefficients on the interaction terms for these dependent variables are always negative, but they are not quite significant at conventional levels (with  $t$ -statistics between  $-1.30$  and  $-1.50$ ).

Thus, the broad picture here is of greater liquidity for mandated and non-mandated USD contracts with the increase being significantly greater for the former. It is fair to say, though, that evidence of a liquidity improvement for mandated contracts from these estimations is less strong than that obtained from comparison of USD and EUR mandated contracts. One interpretation of this finding is that the liquidity improvements in the mandated USD contracts spilled over to non-mandated USD contracts. This may be because market participants might also have chosen to trade non-mandated contracts on SEFs as soon as the functionality became available, and possibly also because, as discussed

above, more transparency for some quoted prices on the USD maturity curve gives market participants a better idea of what a fair quote is for other USD maturities.

### [TABLE 6]

As far as activity and participation are concerned, Table 6 shows that, as for the estimations using the EUR control sample, there are positive effects occurring in the period after Oct. 2, 2013, but only for the mandated contracts.

### **Economic Significance of Liquidity Improvement**

We next assess the economic significance of the observed liquidity improvements by calculating an implied dollar reduction in execution costs for market end-users. The market value of an IRS is set to zero at initiation by selecting the fixed rate such that the present values of the fixed and floating legs are the same. However, a bid-ask spread charged by a dealer on top of the fixed rate, would affect the value of the swap and thus introduce an additional cost incurred by the end-user. The total dollar value of this cost can in principle be approximated by:

$$\text{COST}(\$) \approx \text{SPREAD} \times P \times m \times \text{TRADE\_SIZE} ,$$

where SPREAD is the relative effective spread of a transaction in an IRS contract with a maturity of  $m$  years,  $P$  is the prevailing swap rate and TRADE\_SIZE is the amount of

notional traded. This formula is just the change in the market value of a swap when the swap rate is increased by the (percentage) effective spread.<sup>23</sup>

We extend this approach in order to calculate the *reduction* in execution costs resulting from the trade mandate. In our case, the relative effective spread is approximated by any of the dispersion measures defined in equations (1)-(3). We base these calculations on Test 1 (i.e., the comparison of USD with EUR mandated contracts), because mandated contracts are the most heavily traded segment of the market. Since our difference-in-differences specifications in equation (6) are estimated on a daily basis, we approximate the daily dollar *incremental reduction* in execution costs for USD mandated contracts relative to EUR mandated contracts by:

$$(8) \Delta\text{COST}(\text{USD MAT vs EUR MAT}) \approx (\hat{\beta}_2 + \hat{\beta}_4) \times \bar{P} \times \overline{\text{MATURITY}} \times \overline{\text{VLM}} \times \text{D2C}(\%) ,$$

where  $\hat{\beta}_2, \hat{\beta}_4$  are the estimated coefficients of the date-currency interaction terms in equation (6),  $\bar{P}$  is the average volume-weighted price of the USD mandated contracts (1.7%),  $\overline{\text{MATURITY}}$  is their average volume-weighted maturity (7 years) and  $\overline{\text{VLM}}$  is their average daily volume (\$75 billion). Finally, we multiply with the average fraction of dealer-to-client volume (33%) to estimate the reduction in execution costs that accrues to market end-users. Similarly, the *total reduction* in execution costs for to USD mandated

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<sup>23</sup>The swap rate,  $P$ , is multiplied by the percentage spread and then by notional so as to yield a dollar figure. The cost is incurred every year until maturity with each payment of the fixed rate and therefore multiplied by  $m$ . Note that we sum Dollar costs across years without discounting which, given the historically low interest rates over our sample period, should not change the result very much.

contracts is given by:

$$(9) \quad \Delta\text{COST}(\text{USD MAT}) \approx \left( \sum_{i=1}^4 \hat{\beta}_i \right) \times \bar{P} \times \overline{\text{MATURITY}} \times \overline{\text{VLM}} \times \text{D2C}(\%) ,$$

where here we include the sum of all estimated dummy coefficients  $\hat{\beta}_i$  from equation (6).<sup>24</sup>

This calculation suggests that the effects of the trade mandate are economically significant. The coefficients for the  $\text{CURR} \times \text{DATE}^{(1)}$  and  $\text{CURR} \times \text{DATE}^{(2)}$  terms in the dispersion specifications give an incremental reduction in execution costs for USD mandated versus EUR mandated contracts of between 12% and 19% of previous cross-currency average dispersion levels. This amounts to a *daily* reduction of approximately \$3–\$6 million for end-users. The total reduction in execution costs for USD mandated contracts is larger, at 22% to 32% of previous dispersion levels, which amounts to roughly \$7–\$11 million daily for end-users. The effect on the EUR contracts is also substantial, despite the fact that fewer participants are captured by the mandate. The reduction in execution costs there is 10% to 14% or \$3–\$5 million daily.

### C. Liquidity in D2D versus D2C Trades

In this section we investigate whether the liquidity improvements for SEF-traded contracts are visible both in trades between dealers and clients (D2C) trades and interdealer (D2D) trades. Does SEF trading allow dealers to rebalance inventories more cheaply or are end-users able to enter positions more cheaply or both?

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<sup>24</sup>Note, though, that only the incremental reduction in execution costs can be causally attributed to the trade mandate.

## [TABLES 7 and 8]

In Tables 7 and 8, we re-run our liquidity panel regressions, but where the dependent variable is now constructed from either D2D trades or D2C trades. Unfortunately, we cannot separate either the quoted spread data or the Amihud measure into D2D and D2C components (as they are not based on individual trades) and so we have results only for the dispersion measures. We only report results for the specifications with all the controls.

The first 3 regressions in Tables 7 and 8 indicate that, after the SEF mandate date, D2C trades in the treated group of swaps always experience a liquidity improvement (i.e., dispersion falls), regardless of which control group we use and regardless of the dispersion measure used to approximate liquidity. This increase in liquidity is significant in 5 of the 6 regressions. There is no consistent movement in D2C liquidity for treated group relative to control group swaps on the first event date. Only one of the first event date interactions is significant and that too suggests an improvement in liquidity when SEF trading is available.

For D2D trading, the picture is much less clear. The results, in the last 3 regressions in Tables 7 and 8, show that liquidity of D2D trades in USD mandated contracts improves relative to that of D2D trades in mandated EUR swaps after the SEF mandate date for all of the dispersion measures. However, there is no such improvement in D2D liquidity for mandated USD contracts relative to non-mandated USD contracts. The results suggest that D2D liquidity improves for both mandated and non-mandated USD contracts, in particular after the first event date (with results for one liquidity proxy showing that liquidity improves more for non-mandated contracts than for mandated contracts on this date).



Thus, overall, our regressions show that end-users of swaps have experienced consistent liquidity benefits from mandated SEF trading. The picture for interdealer trades is less clear, in that we do not see uniform evidence that their trading has become less expensive.

## D. SEF Flag Panel Specifications

We next test how the *fraction* of SEF trading affects liquidity and market activity. For this, we utilize the DTCC segment of our data which contains a flag indicating whether a given trade was executed on a SEF. We estimate the following panel specification for mandated USD and EUR-denominated contracts only, on a daily frequency:

$$(10) \quad L_{it} = \alpha_i + \beta_1 \text{SEF}_{it} + \beta_2 \text{DATE}_t^{(1)} + \gamma \text{SWAP\_RV}_{it} + \delta' X_t + \epsilon_{it} ,$$

where  $L_{it}$  is one of the previously defined liquidity or market activity variables for contract  $i$  on day  $t$ ,  $\text{SEF}_{it}$  is the percentage of SEF trading,  $\text{DATE}_t^{(1)}$  is defined as above, and  $X_t$  is the usual vector of controls. We include the date dummy in the specification to control for any effects on the dependent variable related to SEF trading being available regardless of the degree of actual SEF trading. For instance, dealers could be quoting narrower spreads simply because they know that SEF trading is possible and their quotes are potentially subject to comparison and scrutiny by end-users. This effect could materialize regardless of the actual amount of SEF trading.<sup>25</sup> Because it is possible that SEF trading is itself caused

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<sup>25</sup>We also estimate model (10) only using data after the introduction of SEF trading. The results for the liquidity variables are similar to those reported below and for this reason they are omitted.

by market liquidity, we also estimate this model using instrumental variables, instrumenting  $\text{SEF}_{it}$  with its own lags.

## [TABLES 9 and 10]

Tables 9 and 10 show the results of these estimations. The coefficients on the percentage of SEF trading are significant in 14 of the 16 regressions and consistent with previous findings. A higher fraction of SEF trading is associated with increased levels of liquidity (i.e., lower dispersion, spreads and Amihud measures). Similarly, SEF trading is positive and statistically significant in the regressions for activity variables: a higher fraction of SEF trading is associated with higher volumes, more trades and a larger number of market participants. Overall, these results suggest that SEF trading is associated with robust and measurable improvements in market quality.

## V. SEFs and Dealer Market Power

### A. Relationships Between Dealers and Clients

Duffie et al. (2005) and Yin (2005) argue that the beneficial effects of pre-trade transparency on liquidity come via the effect of transparency on dealer competition. More intense dealer competition leads to better prices for customers. We have already seen, in Tables 4 and 6, that the introduction of SEF trading increased the number of parties trading swaps, potentially making these markets more competitive. In this section we explore whether the trading relationships between individual customers and dealers have changed as a result of the CFTC trade mandate. If SEF trading has led to more intense

competition between dealers, we would expect the number of dealers that the average customer trades with to have risen for swaps subject to the SEF trading mandate.

We create a variable,  $NDEALERS_{it}$ , that counts the number of unique dealers with whom customer  $i$  trades in month  $t$ , based on trades across all EUR and USD mandated swaps. As a first pass, we aggregate  $NDEALERS_{it}$  across months and end-users for the period before mandatory SEF trading and then do the same for the period after the mandate came into force. Figure 4 displays the frequency distributions of those two samples. It is clear that SEF trading is associated with a dramatic rightwards shift in the distribution. For example, prior to the cutoff date, around 28% of customers traded only with a single dealer. After the SEF trading mandate, this number dropped to 8%. Similarly, prior to Feb. 2014, over 50% of customers dealt with 3 or fewer dealers, while after this date the corresponding number was around 20%.

**[FIGURE 4]**

These numbers immediately suggest that there have been profound changes in the nature of the interactions between swap dealers and customers. The improvements in pre-trade transparency have weakened the ties between individual customers and particular dealers: customer search costs have fallen and thus it has become easier for customers to trade with the dealer showing the best price. Thus, effective competition between dealers has risen and, as shown above, this has led to lower execution costs.

As the CFTC trade mandate only captures U.S. persons, one would also expect any changes in the dealer-client relationships to be more pronounced for U.S. persons. To test this, we estimate a difference-in-differences model using the cross-section of all clients in our

sample. Using our  $\text{NDEALERS}_{it}$  variable for every customer and every month, we estimate

$$\begin{aligned}
(11) \quad \text{NDEALERS}_{it} = & a_i + b \text{U\_S}_i \\
& + c_1 \text{DATE}_t^{(1)} + c_2 (\text{DATE}_t^{(1)} \times \text{U\_S}_i) + c_3 (\text{DATE}_t^{(1)} \times \text{ACTIVE}_i) \\
& + d_1 \text{DATE}_t^{(2)} + d_2 (\text{DATE}_t^{(2)} \times \text{U\_S}_i) + d_3 (\text{DATE}_t^{(2)} \times \text{ACTIVE}_i) \\
& + f_1 \text{ACTIVE}_i + f_2 (\text{U\_S}_i \times \text{ACTIVE}_i) + f_3 (\text{DATE}_t^{(1)} \times \text{U\_S}_i \times \text{ACTIVE}_i) \\
& + f_4 (\text{DATE}_t^{(2)} \times \text{U\_S}_i \times \text{ACTIVE}_i) + \gamma' X_{it} + u_{it} ,
\end{aligned}$$

where  $t$  denotes months,  $i$  indexes end-users and  $a_i$  is a fixed effect for end-user  $i$ . The date dummies are defined as above. The  $X_{i,t}$  vector contains end-user specific trading activity variables (including number of trades and total volume executed).  $\text{U\_S}$  is a dummy for clients that are U.S.-persons, while  $\text{ACTIVE}_{it}$  is a dummy that identifies a client who trades at least 20 times per month on average (i.e., roughly once a day or more). In our data, there are a large number of end-users who trade very infrequently (e.g., once a week or less) and for whom  $\text{NDEALERS}_{it}$  is thus always low regardless of the trading environment. So, in order to focus on clients for whom increased dealer competition and greater liquidity is going to be most valuable, we separate the active from the less active clients in the dummy specification in the regression

Table 11 shows the results of this estimation. The implementation of the SEF trading mandate leads to the active set of U.S. clients executing against a significantly larger number of dealers. Prior to the mandate date, and focussing on the results without control variables for clarity of interpretation, the significant coefficients indicate that those

active U.S. clients dealt with around 9 dealers per month on average and afterwards this increases by around 17%, or 1.6 dealers, on average. This change is statistically significant, while there are no significant shifts for non-U.S. or inactive clients. The specification with control variables yields qualitatively similar findings, although in that case the less active U.S. clients see a small, marginally significant drop in the number of dealers they trade with after the mandate date.

### [TABLE 11]

Thus, our graphical and econometric evidence is consistent. After the introduction of mandatory SEF trading competition between dealers intensified, particularly for the set of active U.S. clients, and this likely contributes to the fall we observe in clients' trading costs.

## **B. The Geography of Trading and Dealer Market Power**

Shortly after the SEF trading mandate took effect, one concern among market participants and regulators was that it might lead the global swaps market to fragment along geographical lines (ISDA (2014)). Since the mandate only applied to U.S. persons it was conceivable that, for example, European counterparties who wished to avoid trading on a SEF might do so by trading exclusively with other European counterparties. Indeed, some reports released after the implementation of the mandate suggested that the market was fragmenting and that this was causing market quality to deteriorate (e.g., Giancarlo (2015)).

To shed light on this issue, we exploit the data on counterparty identities for the LCH trades. We classify market participants as either U.S. or non-U.S.-based and calculate the percentage of trading volume executed between those two groups (U.S.-to-non-U.S.).

**[FIGURE 5]**

Figure 5 plots this percentage for USD and EUR-denominated contracts. It is evident that after the introduction of SEF trading there is a clear reduction in the fraction of U.S.-to-non-U.S. volume in EUR-denominated swaps, from around 20% to 5%. There is no similar effect in USD contracts. More formally, the first two columns of Table 12 show the results of time-series regressions of the fractions of U.S.-to-non-U.S. volumes in USD and EUR contracts on the SEF introduction event dummy and a number of controls. The dummy coefficient is highly significant and negative for the EUR contracts and insignificant for USD contracts. Thus the EUR segment of the swap market became significantly more geographically fragmented following the introduction of SEF trading.

**[TABLE 12]**

As previously discussed, it is likely that the observed difference between the two market segments is because of the much smaller proportion of U.S. market players in EUR-denominated swaps trading. If a non-U.S. counterparty wants to trade with a non-U.S. counterparty and avoid SEF execution, this is much simpler for a EUR-denominated contract than for a USD-denominated one. Given the preponderance of U.S. persons trading USD swaps, it is hard to avoid trading with a U.S. person and thus on a SEF.

However, given the beneficial effects of SEF trading, the obvious question is why any (and which) counterparties might want to avoid trading on SEFs. Figure 6 shows a breakdown of the fraction of U.S.-to-non-U.S. volume in the EUR-denominated contracts according to the type of counterparties. It is clear that the observed fragmentation is entirely driven by interdealer trading and the last two columns of Table 12 confirm this. Thus, it appears that it is swap dealers who are trying to avoid using SEFs where possible. There is no observable fragmentation for EUR trades that involve at least one non-dealer. This might have been expected, as there is no incentive for customers to avoid trading on SEFs given the liquidity improvements they offer.

**[FIGURE 6]**

The question that remains is why cross-border activity by EUR swap dealers dropped so clearly when the SEF trading mandate was introduced in the United States. One possibility is that interdealer trading between U.S.-based and non-U.S.-based dealers could genuinely have exogenously declined and could have been replaced by local (intra-U.S. and intra-European) trading. Alternatively, interdealer trades between U.S. and non-U.S. firms could have been executed by the non-U.S. branches of swap dealers who happen to have trading desks in multiple jurisdictions. For example, a trade in EUR between a U.S. and a European dealer that was being executed by the U.S. desk of the former, could now be executed by the European desk of the same dealer. In this case, it would be registered as an intra-European trade and would not be subject to the SEF trade mandate.

**[FIGURES 7 and 8]**

To see if this is the case, we plot in Figure 7 the fraction of interdealer trading in EUR contracts done by the U.S. and non-U.S. trading desks of only those swap dealers who have desks in multiple jurisdictions and who execute more than 10% of their swap volumes from a desk located in the United States. The figure shows that there is a sharp shift in interdealer activity from the U.S. desks to the non-U.S. ones. The fraction of non-U.S. desk trading increases from a daily average of 75% prior to the introduction of SEFs, to an average of 95% after (with the corresponding fraction of U.S. desk trading dropping from 25% to 5%). Additionally, Figure 8 shows that there is virtually no change in the amount of interdealer trading done exclusively by dealers who regularly trade the bulk (i.e., more than 90%) of their derivatives from their European desks. We interpret this as implying that the observed geographical fragmentation is artificial in the sense that it is entirely driven by EUR swap dealers in large institutions using their non-U.S. desks to do business that would previously have passed through their U.S. desk.

These results are consistent with (although not direct proof of) swap dealers strategically choosing the location of the desk executing a particular trade in order to avoid trading in a more transparent and competitive setting. A potential explanation for this lies in attempts to maintain market power. By shifting the location of the interdealer market in EUR swaps to Europe and using European entities to execute, the SEF trading mandate and the associated CFTC impartial access requirements are avoided.<sup>26</sup> This allows dealers to retain power, in that they retain control over who they trade with and how, which in turn would allow them to exclude any potential new competitors from interdealer trading.

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<sup>26</sup>The CFTC guidance is available at: <https://www.cftc.gov/idc/groups/public/@newsroom/documents/file/dmostaffguidance111413.pdf>



If a potential competitor cannot access interdealer markets to manage inventory, their quotes are likely to be less tight and thus they are less likely to attract business in the customer market.

## **VI. Summary and Conclusion**

One of the pillars of the G20 reform agenda for OTC derivatives markets is the requirement to migrate trading activity to more centralized, more transparent venues. In response, as part of Dodd–Frank, U.S. regulators have mandated that U.S. persons should trade certain IRS contracts on SEFs. These venues improve transparency by automatically disseminating requests for quotes to multiple dealers and by featuring an electronic order book which allows any market participant to compete with dealers for liquidity provision by posting quotes. Thus, SEFs induce competition between existing dealers and also lower the barriers to potential entrants to the dealing community.

Using transaction data from the IRS market we assess the impact of SEF introduction on swap market activity and liquidity. Our findings suggest that the move from an OTC to a more centralized, competitive market structure leads to a reduction in execution costs. This is more pronounced for mandated USD contracts as these are primarily traded by U.S. persons who are captured by the trade mandate. For these contracts, dispersion-based liquidity measures show that liquidity improves by 12% to 19% relative to EUR mandated contracts. This amounts to daily savings in execution costs of as much as \$3–\$6 million for end-users of USD swaps.

We then demonstrate that the introduction of centralized trading resulted in a sharp increase in competition between swap dealers. The average active U.S. client in this market trades with a significantly greater number of dealers after the centralized trading mandate. Thus, dealer competition rises and liquidity improves, as one would expect.

Additionally, we find that, for the EUR-denominated swap market, the bulk of interdealer trading previously executed between U.S. and non-U.S. trading desks is now largely executed by the non-U.S. (mostly European) trading desks of the same institutions (i.e., banks have shifted interdealer trading of their EUR swap positions from their U.S. desks to their European desks). We interpret this as an indication that swap dealers wish to avoid being captured by the SEF trading mandate and the associated impartial access requirements. Migrating the EUR interdealer volume off-SEFs enables dealers to choose who to trade with and (more importantly) who not to trade with. This might allow them to erect barriers to potential entrants to the dealing community. Thus this fragmentation of the global market may be interpreted as dealers trying to retain market power, where possible. Importantly, we find no evidence that customers in EUR swap markets try to avoid SEF trading and the improved liquidity it delivers.

Overall, given the global nature of OTC derivatives markets, our findings suggest that extending the scope of the trading mandate to cover other sufficiently liquid swap markets could be beneficial. Such regulation was implemented at the start of 2018 in the EU as part of MiFIR.

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FIGURE 1

Total Traded Volume (in \$ billion) by Currency.

Figure 1 shows the total volume of EUR-denominated and USD-denominated plain vanilla swaps.

The sample covers every spot vanilla interest rate swap which was either cleared by LCH or reported to DTCC between Jan. 1, 2013 and Sept. 15, 2014.

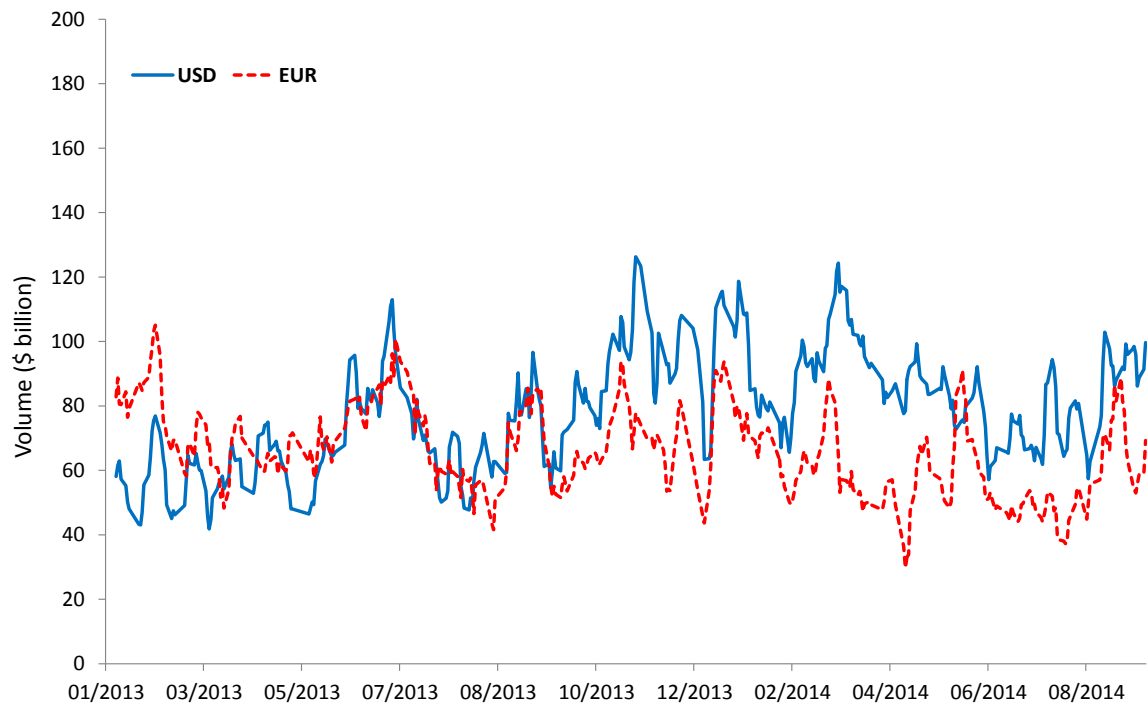


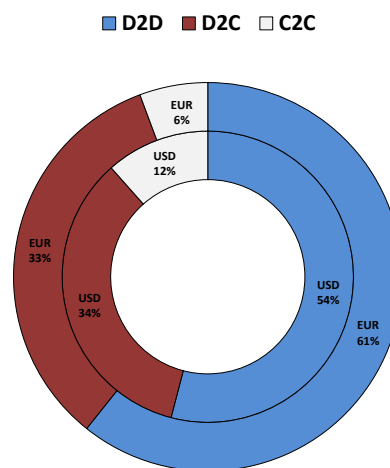


FIGURE 2

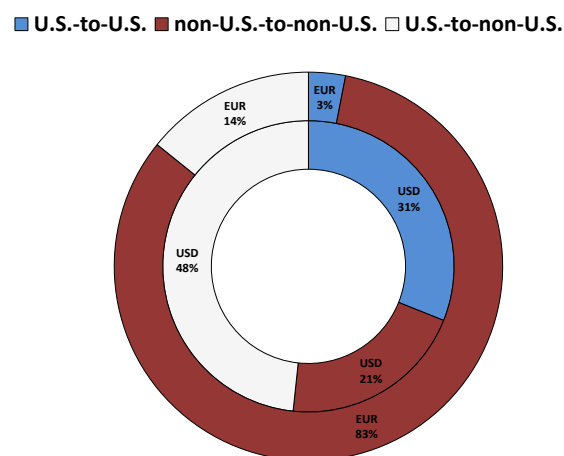
Volume Shares by Type of Counterparty or Location.

Figure 2 decomposes the total volume into i) dealer-to-dealer (D2D), dealer-to-client (D2C), and client-to-client (C2C) trading; and ii) U.S.-to-U.S., U.S.-to-non-U.S., and non-U.S.-to-non-U.S. trading. The inner circle presents the volumes of USD-denominated swaps, while the outer circle presents the volumes of EUR-denominated swaps. The sample covers every spot vanilla interest rate swap which was cleared by LCH between Jan. 1, 2013 and Sept. 15, 2014.

*Graph A. Dealer/Client Volume*



*Graph B. U.S./non-U.S. Volume*

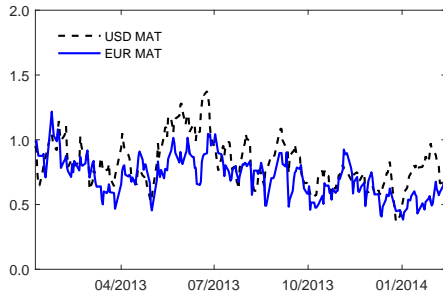


### FIGURE 3

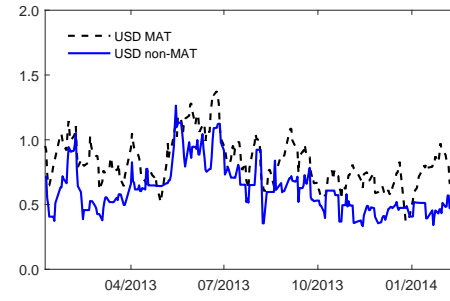
#### Parallel Trends.

Figure 3 shows the evolution of our key liquidity measures, for treated and control samples, prior to the second event date. The liquidity measures shown are smoothed price dispersions, quoted spreads and the Amihud measure and they have been averaged across the members of the relevant set of contracts on each date.

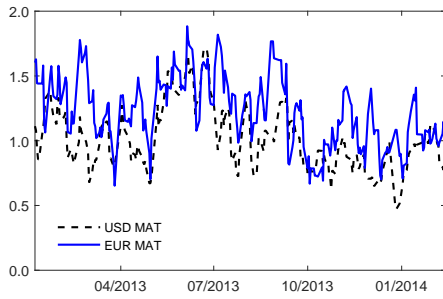
Graph A. DISP\_VW: USD MAT vs EUR MAT



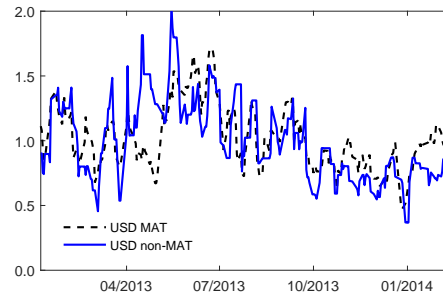
Graph B. DISP\_VW: USD MAT vs non-MAT



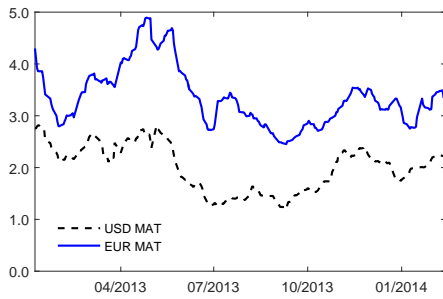
Graph C. DISP\_JNS: USD MAT vs EUR MAT



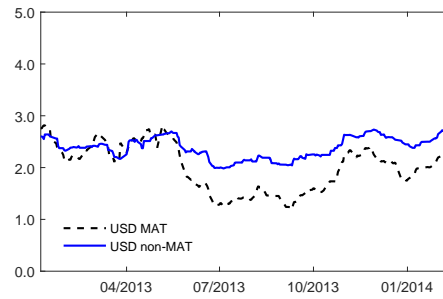
Graph D. DISP\_JNS: USD MAT vs non-MAT



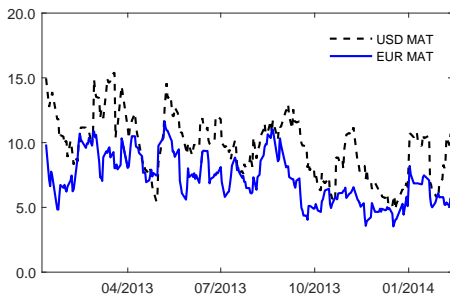
Graph E. QSPREAD: USD MAT vs EUR MAT



Graph F. QSPREAD: USD MAT vs non-MAT



Graph G. AMIHUD: USD MAT vs EUR MAT



Graph H. AMIHUD: USD MAT vs non-MAT

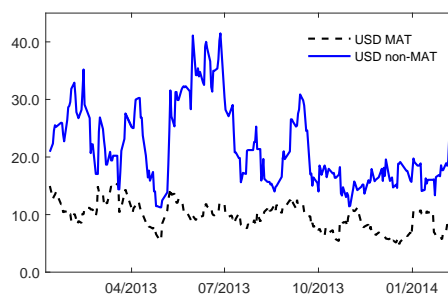
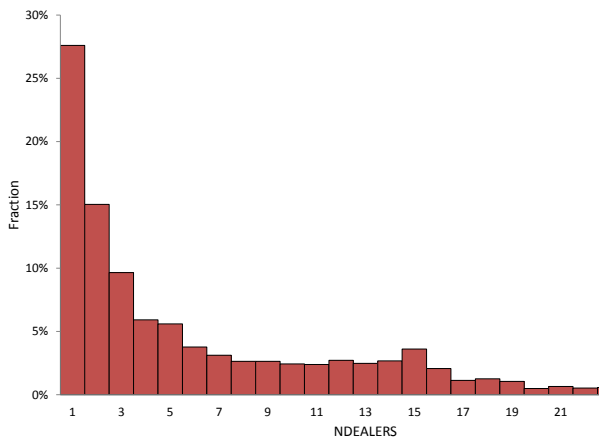


FIGURE 4

Number of Dealers per Client.

Figure 4 shows the frequency distribution of the number of dealers with whom end-users trade before and after Feb. 2014, when SEF trading becomes mandatory for all U.S. persons trading any mandated IRS contracts. The time period is Jan. 1, 2013 to Sept. 15, 2014.

*Graph A. Pre-Feb. 2014*



*Graph B. Post-Feb. 2014*

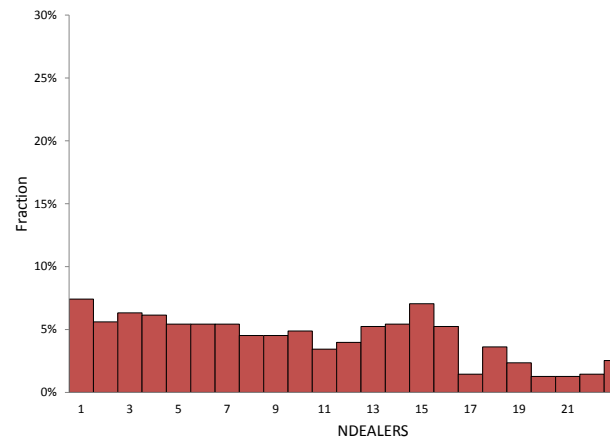


FIGURE 5

Fraction of U.S.-to-non-U.S. Trading.

Figure 5 shows the percentage of U.S.-to-non-U.S. trading in USD- and EUR-denominated swaps. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (Oct. 2, 2013). The time period is Jan. 1, 2013 to Sept. 15, 2014.

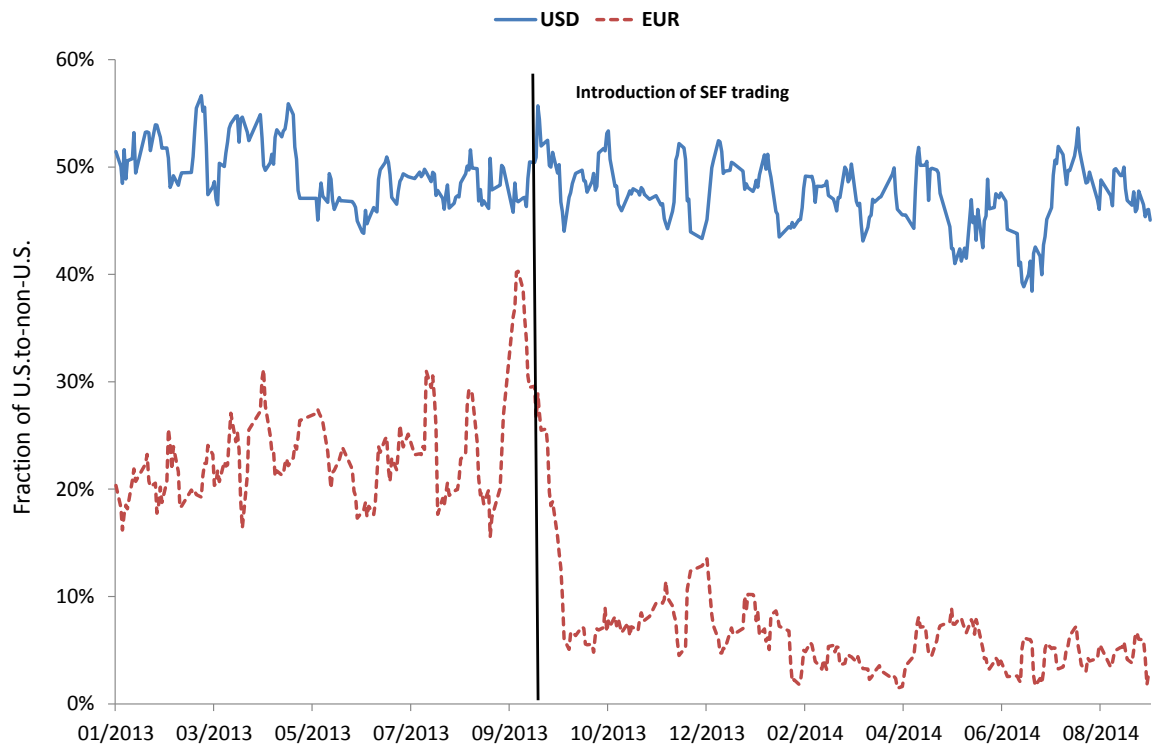


FIGURE 6

Breakdown of U.S.-to-non-U.S. Trading.

Figure 6 shows the breakdown of U.S.-to-non-U.S. trading volume in EUR-denominated swaps into interdealer volume and all other trading volume. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (Oct. 2, 2013). The time period is Jan. 1, 2013 to Sept. 15, 2014.

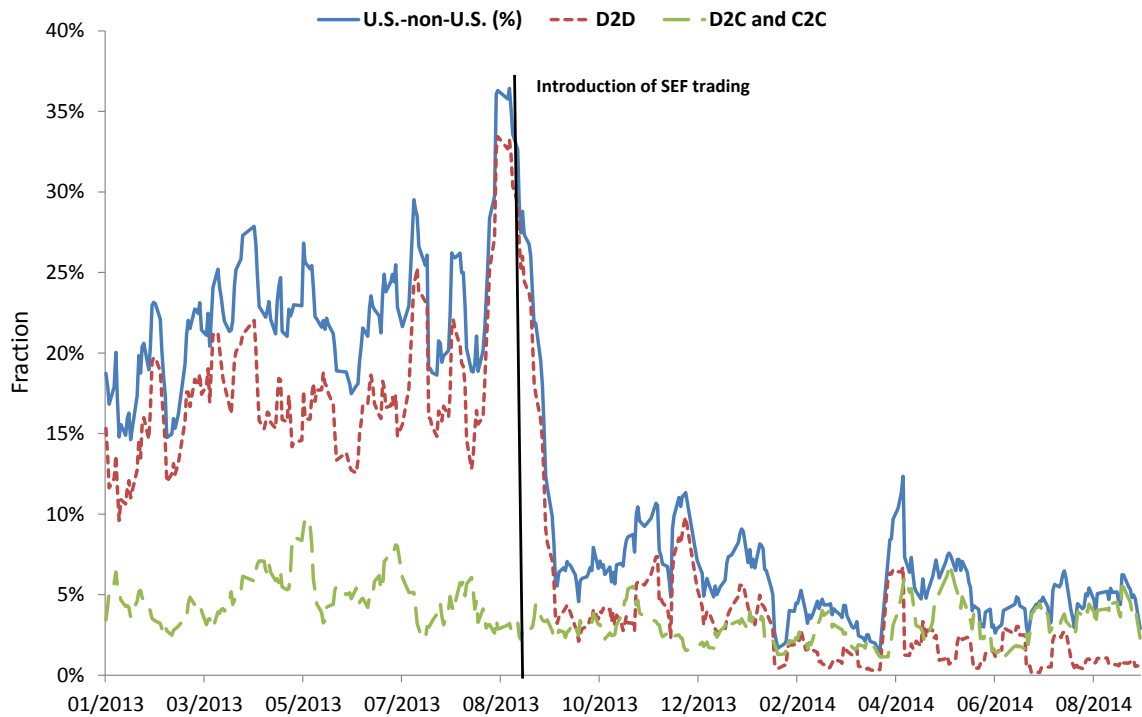


FIGURE 7

Breakdown of Interdealer Volume by Trading Desk Location.

Figure 7 plots the fractions of interdealer trading in EUR-denominated swaps executed by U.S. and non-U.S. trading desks, for all swap dealers that have trading desks in the United States and at least one more jurisdiction. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (Oct. 2, 2013). The time period is Jan. 1, 2013 to Sept. 15, 2014.

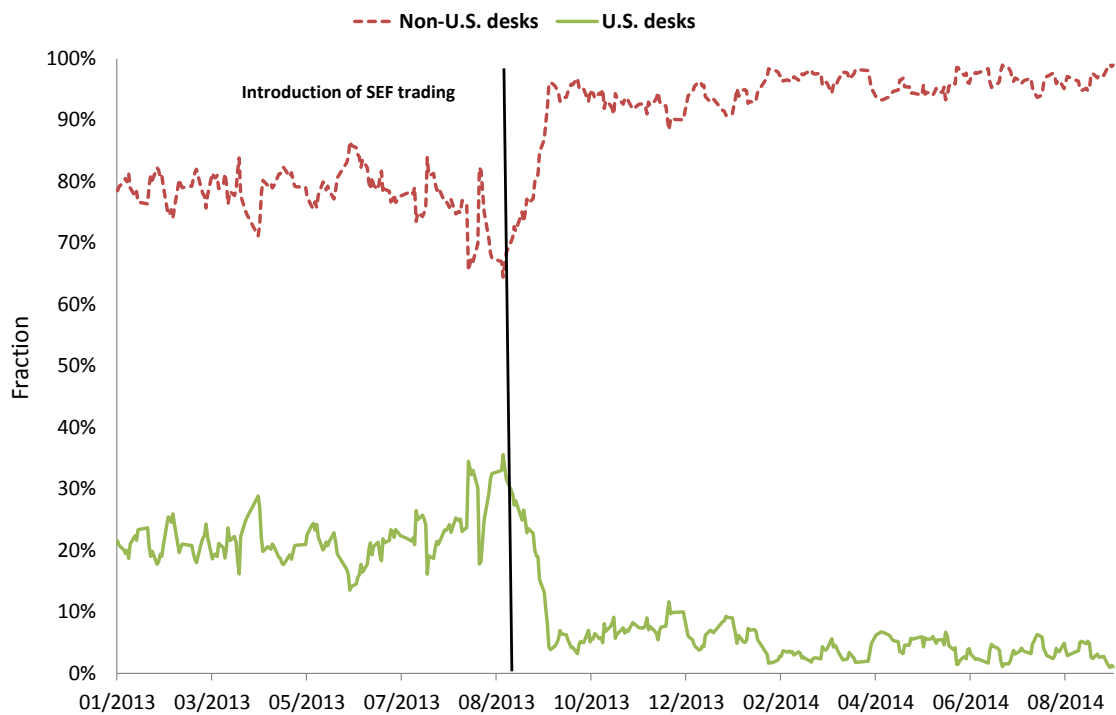


FIGURE 8

Interdealer Trading by Swap Dealers with No U.S. Trading Desks.

Figure 8 plots the amount of interdealer trading in EUR-denominated swaps executed exclusively by swap dealers that have no trading desks in the United States. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (Oct. 2, 2013). The time period is Jan. 1, 2013 to Sept. 15, 2014.

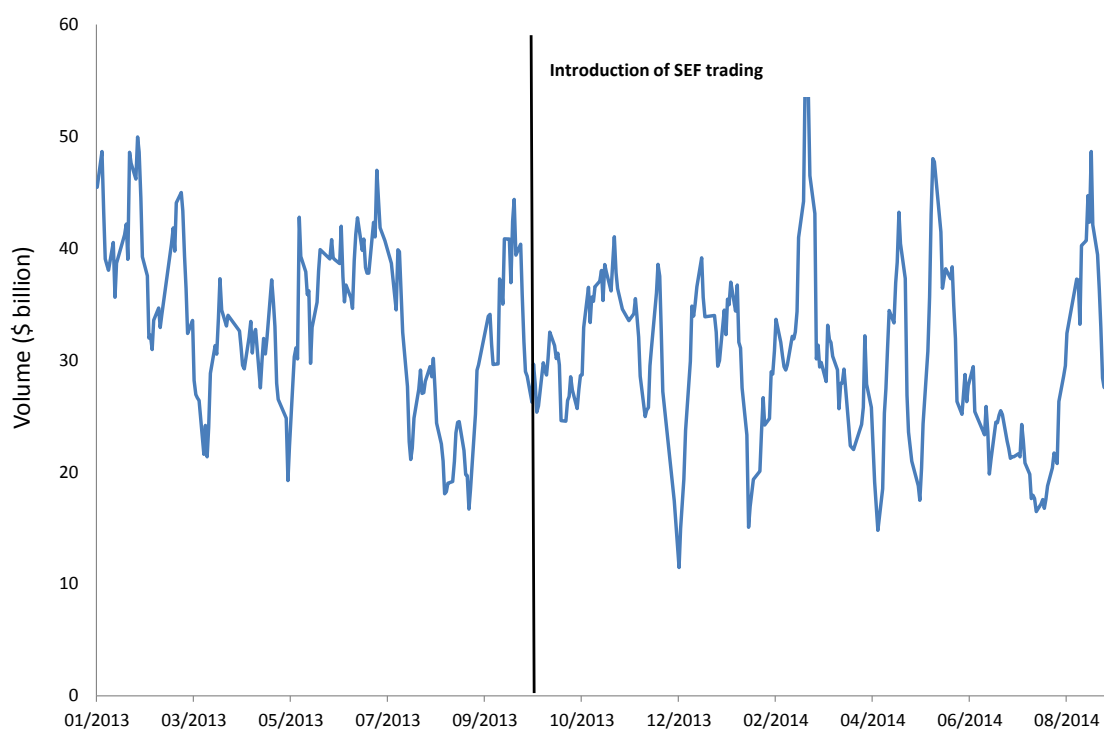




TABLE 1

SEF Trading Mandate Dates.

Table 1 shows the SEF trading mandate dates by currency and maturity for plain vanilla IRS contracts used in our study.

Currency	Maturity	Effective Date
USD	2, 3, 5, 7, 10, 12, 15, 20, 30	15/02/2014
EUR	2, 3, 5, 7, 10, 12, 15, 20, 30	15/02/2014
USD	4, 6	26/02/2014
EUR	4, 6	26/02/2014

TABLE 2

Summary Statistics by Currency.

Table 2 presents summary statistics of daily values of the key variables, by currency. It shows statistics on trading volume (VLM) measured in \$ billions; daily number of trades (NTRADES); daily unique number of active counterparties (NPARTIES); the fraction of SEF (SEF), dealer-to-dealer (D2D), and U.S. to non-U.S. (U.S.-to-non-U.S.) trading. It also shows statistics on the three dispersion measures, the Amihud price impact measure and the quoted spread as defined in equations (1)- (5). The data consists of all LCH and DTCC reported transactions for USD- and EUR-denominated plain vanilla swaps. The time period is Jan. 1, 2013 to Sept. 15, 2014.

Variables	USD					EUR				
	Mean	StDev	Min	Max	<i>N</i>	Mean	StDev	Min	Max	<i>N</i>
<b><i>Panel A: Liquidity variables</i></b>										
DISP_VW(%)	0.72	0.47	0	4.16	5,875	0.66	0.46	0	3.67	5,463
DISP_JNS(%)	0.91	0.58	0.05	4.29	5,875	1.16	0.82	0.07	4.60	5,463
DISP_BZ(%)	1.15	0.90	0	5.67	5,875	0.68	0.87	0	6.10	5,463
AMIHU	14.52	42.03	0.00	1031.75	5,870	9.50	17.49	0.00	447.32	5,817
QSPREAD(%)	2.11	1.89	0.39	9.95	5,742	3.68	3.48	0.55	42.68	5,817
<b><i>Panel B: Activity variables</i></b>										
VLM (\$ billion)	5.66	7.36	0.02	64.58	5875	4.44	4.49	0.06	44.90	5,463
NTRADES	72.88	95.18	4	676	5875	39.82	45.36	4	346	5,463
NPARTIES	22.04	12.25	2	61	5740	19.68	8.59	2	49	5,791
<b><i>Panel C: Market structure</i></b>										
SEF (%)	0.48	0.44	0	1	5820	0.20	0.32	0	1	5,072
D2D (%)	0.54	0.24	0	1	5740	0.61	0.21	0	1	5,791
U.S.-to-non-U.S. (%)	0.48	0.21	0	1	5740	0.14	0.16	0	0.96	5,791

TABLE 3

Panel Difference-in-Differences Specification for Liquidity Variables.

Table 3 shows estimation results of equation (6), where the treatment group are the USD mandated contracts and the control group are the EUR mandated contracts. The liquidity metrics are defined in equations (1)–(5).  $DATE^{(1)}$  is a dummy variable that takes the value of 1 after the introduction of SEF trading on Oct. 2, 2013 and  $DATE^{(2)}$  is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1.  $CURR$  is a dummy that takes the value 1 for USD-denominated contracts, and 0 otherwise.  $SWAP\_RV$  is the daily maturity/currency-specific realized variance of each swap contract calculated using a 30-day rolling window.  $VIX$  and  $VDAX$  are the S&P 500 and DAX volatility indices and  $\log R_{SP500}$  and  $\log R_{DAX}$  are the daily log returns on the indices themselves.  $O/N\_SPREAD\_USD$  and  $O/N\_SPREAD\_EUR$  are the differences between the overnight unsecured borrowing rates and the respective central bank rates.  $SLOPE\_USD$  and  $SLOPE\_EUR$  are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries, respectively. The model is estimated using maturity and currency fixed effects. Standard errors are clustered by maturity and currency. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 3 (continued)

USD mandated vs. EUR mandated - Liquidity variables											
	DISP_VW	DISP_VW	DISP_JNS	DISP_JNS	DISP_BZ	DISP_BZ	QSPREAD	QSPREAD	AMIHUD	AMIHUD	AMIHUD
DATE <sup>(1)</sup>	-0.2121*** (-10.98)	-0.2202*** (-7.16)	-0.3284*** (-12.44)	-0.3435*** (-6.87)	-0.2734*** (-6.28)	-0.2406*** (-5.82)	-0.0033*** (-3.09)	0.0015 (1.34)	-2.0908*** (-5.86)	-0.4027 (-0.49)	
CURR × DATE <sup>(1)</sup>	0.0162 (0.50)	-0.0067 (-0.21)	0.0711* (1.84)	0.0472 (1.08)	-0.0154 (-0.25)	-0.0715 (-1.36)	0.0038*** (3.06)	0.0038** (2.17)	-0.1595 (-0.14)	-0.0472 (-0.04)	
DATE <sup>(2)</sup>	0.1061*** (4.40)	0.0274 (0.97)	0.2056*** (5.05)	0.0550 (1.11)	0.1155*** (3.39)	0.0908** (2.57)	0.0110*** (3.39)	0.0049** (2.55)	2.8727*** (5.56)	1.6492*** (3.02)	
CURR × DATE <sup>(2)</sup>	-0.1345*** (-4.85)	-0.0958** (-2.71)	-0.2178*** (-4.94)	-0.1514** (-2.00)	-0.2152*** (-4.68)	-0.1674*** (-3.62)	-0.0120*** (-3.39)	-0.0074*** (-3.12)	-2.5622* (-2.00)	-2.2233* (-1.81)	
SWAP_RV		34.3884* (1.89)		55.9020* (1.82)		45.4654*** (2.91)		4.0545*** (4.39)		323.0161* (1.82)	
VIX		0.0106** (2.78)		0.0092* (1.84)		0.0234*** (3.69)		-0.0003*** (-3.51)		-0.3149 (-1.71)	
VDAX		0.0105** (2.39)		0.0218*** (3.41)		0.0061 (0.78)		-0.0006* (-1.95)		0.0485 (0.71)	
log <i>R</i> <sub>SP500</sub>		-2.5999** (-2.81)		-3.2044*** (-3.22)		-3.8063* (-1.73)		-0.0036 (-0.50)		-73.9144*** (-2.40)	
log <i>R</i> <sub>DAX</sub>		1.2973* (2.05)		-2.2878* (-1.81)		6.0851*** (5.59)		0.0158** (2.66)		-54.2685*** (-2.09)	
SLOPE_USD		-0.1114*** (-3.15)		-0.1412** (-2.75)		-0.2107*** (-4.42)		-0.0118*** (-5.03)		-0.3990 (-0.32)	
SLOPE_EUR		0.0147 (0.26)		-0.0030 (-0.04)		0.1283 (1.59)		-0.0021 (-0.82)		-1.3469 (-0.89)	
O/N_Spread_USD		-0.4118** (-2.44)		-0.0678 (-0.30)		-1.3549*** (-3.69)		-0.0014 (-0.68)		-9.0355 (-0.75)	
O/N_Spread_EUR		0.3761*** (6.09)		0.6027*** (5.82)		0.3735*** (4.92)		0.0088*** (3.39)		-3.4391 (-0.98)	
CONSTANT	0.8362*** (91.65)	0.8365*** (7.60)	1.2040*** (107.22)	1.2242*** (7.70)	1.1541*** (71.52)	0.9887*** (5.30)	0.0275*** (39.65)	0.0671*** (5.99)	9.5040*** (51.45)	14.1409*** (7.93)	
<i>Within-R</i> <sup>2</sup>	0.054 8,821	0.077 8,205	0.040 8,821	0.067 8,205	0.032 8,821	0.044 8,205	0.078 8,688	0.313 8,073	0.003 8,818	0.005 8,202	

TABLE 4

Panel Difference-in-Differences Specification for Activity Variables.

Table 4 shows estimation results of equation (6), where the treatment group are the USD mandated contracts and the control group are the EUR mandated contracts. VLM is the amount of gross notional traded in U.S. dollars, NTRADES is the number of trades executed and NPARTIES is the number of unique counterparties active on a given day. DATE<sup>(1)</sup> is a dummy variable that takes the value of 1 after the introduction of SEF trading on Oct. 2, 2013 and DATE<sup>(2)</sup> is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1. CURR is a dummy that takes the value 1 for USD-denominated contracts, and 0 otherwise. SWAP\_RV is the daily maturity/currency-specific variance of each swap contract calculated using a 30-day rolling window. VIX and VDAX are the S&P 500 and DAX volatility indices and  $\log R_{\text{SP500}}$  and  $\log R_{\text{DAX}}$  are the daily log returns on the indices themselves. O/N\_SPREAD\_USD and O/N\_SPREAD\_EUR are the differences between the overnight unsecured borrowing rates and the respective central bank rates. SLOPE\_USD and SLOPE\_EUR are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. The model is estimated using maturity and currency fixed effects. Standard errors are clustered by maturity and currency. Robust *t*-statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 4 (continued)

USD mandated vs. EUR mandated - Activity variables						
	VLM	VLM	NTRADES	NTRADES	NPARTIES	NPARTIES
DATE <sup>(1)</sup>	-0.3433** (-2.61)	-0.4270** (-2.56)	-4.2991*** (-2.91)	-6.3279*** (-3.46)	0.0583 (0.27)	-0.4482 (-1.06)
CURR $\times$ DATE <sup>(1)</sup>	2.4496*** (3.15)	2.1238*** (2.85)	22.4662*** (3.29)	18.7042*** (2.95)	1.4968** (2.26)	0.8772 (1.39)
DATE <sup>(2)</sup>	-0.7535** (-2.74)	-0.6740 (-1.69)	-6.4935** (-2.37)	-10.7412** (-2.32)	-1.1243*** (-3.06)	-1.4809*** (-3.70)
CURR $\times$ DATE <sup>(2)</sup>	0.3077 (0.77)	0.3333 (0.77)	4.0289 (1.16)	4.0268 (1.08)	1.1234** (2.11)	1.0083* (1.91)
SWAP_RV		20.8778 (0.20)		-141.3714 (-0.16)		-121.3896 (-0.63)
VIX		-0.0227 (-0.79)		0.2091 (0.68)		0.0460 (0.90)
VDAX		0.1549*** (3.23)		1.6553*** (3.12)		0.2651*** (4.54)
log $R_{SP500}$		-6.0106 (-1.13)		-48.2967 (-0.90)		4.5398 (0.54)
log $R_{DAX}$		-4.2459 (-1.12)		-119.4527** (-2.10)		-11.2663 (-1.66)
SLOPE_USD		-0.3819 (-0.96)		-3.2920 (-0.89)		0.6334 (0.97)
SLOPE_EUR		1.2889** (2.83)		3.0552 (0.59)		0.2681 (0.31)
O/N_SPREAD_USD		-0.8503 (-0.78)		-1.8934 (-0.17)		-0.5551 (-0.19)
O/N_SPREAD_EUR		2.1692*** (3.83)		28.1735*** (3.54)		3.1105*** (3.36)
CONSTANT	5.6516*** (25.80)	2.9138** (2.24)	64.8541*** (30.44)	51.1500*** (3.92)	23.0793*** (100.95)	18.1139*** (11.02)
Within- $R^2$ $N$	0.042 8,821	0.049 8,205	0.033 8,821	0.043 8,205	0.013 8,821	0.028 8,205

TABLE 5

Panel Difference-in-Differences Specification for Liquidity Variables.

Table 5 shows estimation results of specification (7), where the treatment group consists of the USD mandated contracts and the control group of the USD non-mandated contracts. The liquidity metrics are defined in equations (1)–(5).  $\text{DATE}^{(1)}$  is a dummy variable that takes the value of 1 after the introduction of SEF trading on Oct. 2, 2013 and  $\text{DATE}^{(2)}$  is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1.  $\text{MAT}$  is a dummy that takes the value 1 for mandated contracts, and 0 otherwise.  $\text{SWAP\_RV}$  is the daily maturity/currency-specific realized variance of each swap contract calculated using a 30-day rolling window.  $\text{VIX}$  and  $\text{VDAX}$  are the S&P 500 and DAX volatility indices and  $\log R_{\text{SP500}}$  and  $\log R_{\text{DAX}}$  are the daily log returns on the indices themselves.  $\text{O/N\_SPREAD\_USD}$  and  $\text{O/N\_SPREAD\_EUR}$  are the differences between the overnight unsecured borrowing rates and the respective central bank rates.  $\text{SLOPE\_USD}$  and  $\text{SLOPE\_EUR}$  are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. Standard errors are clustered by maturity. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 5 (continued)

	USD mandated vs. USD non-mandated - Liquidity variables									
	DISP_VW	DISP_VW	DISP_JNS	DISP_JNS	DISP_BZ	DISP_BZ	QSPREAD	QSPREAD	AMIHU	AMIHU
DATE <sup>(1)</sup>	-0.2220*** (-3.87)	-0.2362*** (-4.72)	-0.3372*** (-6.37)	-0.3269*** (-6.91)	-0.2520*** (-3.60)	-0.3097*** (-5.21)	0.0017 (0.94)	0.0052*** (3.09)	-12.6410* (-1.89)	-9.5547 (-1.75)
MAT $\times$ DATE <sup>(1)</sup>	0.0261 (0.41)	0.0273 (0.47)	0.0799 (1.33)	0.0694 (1.25)	-0.0367 (-0.44)	-0.0091 (-0.12)	-0.0012 (-0.64)	0.0002 (0.10)	10.3859 (1.53)	12.1055 (1.55)
DATE <sup>(2)</sup>	0.0304 (1.73)	0.0140 (0.64)	0.0582** (2.18)	0.0023 (0.06)	-0.0171 (-0.74)	0.0137 (0.40)	0.0012*** (4.52)	0.0019*** (3.19)	8.7194 (1.37)	5.2508 (1.09)
MAT $\times$ DATE <sup>(2)</sup>	-0.0589** (-2.63)	-0.0611** (-2.65)	-0.0704** (-2.23)	-0.0742** (-2.26)	-0.0827* (-2.12)	-0.0764* (-2.08)	-0.0022 (-1.50)	-0.0010 (-1.30)	-8.4310 (-1.30)	-8.6509 (-1.35)
SWAP_RV		4.0546 (0.44)		3.4620 (0.28)		29.2650* (1.83)		2.6261*** (11.41)		172.3148 (0.88)
VIX		0.0091* (2.01)		0.0067 (1.30)		0.0209** (2.54)		-0.0002** (-2.52)		-0.8607 (-1.33)
VDAX		0.0212*** (4.31)		0.0307*** (4.11)		0.0294** (2.78)		-0.0003*** (-3.70)		0.7018 (1.10)
$\log R_{SP500}$		-5.9413*** (-7.76)		-5.5260*** (-4.34)		-10.8943*** (-4.42)		0.0001 (0.02)		-36.4589 (-0.41)
$\log R_{DAX}$		1.8209*** (3.04)		0.5032 (0.62)		5.2805*** (3.62)		0.0014 (0.48)		-203.7765* (-1.92)
SLOPE_USD		-0.3664 (-1.74)		-0.6720*** (-3.12)		-0.6065 (-1.54)		0.0017 (0.93)		-19.8318 (-0.98)
SLOPE_EUR		0.3598*** (5.48)		0.4618*** (6.12)		0.4900*** (5.28)		0.0065*** (5.14)		-4.9971 (-0.81)
O/N_SPREAD_USD		-0.1404*** (-4.83)		-0.2023*** (-5.38)		-0.1637** (-2.75)		-0.0122*** (-4.03)		-2.5034 (-0.95)
O/N_SPREAD_EUR		0.1176** (2.78)		0.1080 (1.64)		0.2354** (2.88)		0.0064** (2.33)		-3.6189 (-1.32)
CONSTANT	0.8441*** (65.67)	0.6170*** (5.07)	1.0916*** (69.89)	0.9398*** (5.73)	1.3402*** (71.15)	0.6650** (2.50)	0.0208*** (51.41)	0.0403*** (8.37)	16.4692*** (34.91)	26.7056*** (3.80)
Within- $R^2$	0.065	0.098	0.065	0.092	0.044	0.072	0.014	0.397	0.004	0.009
N	5,875	5,453	5,875	5,453	5,875	5,453	5,742	5,321	5,090	5,041



TABLE 6

Panel Difference-in-Differences Specification for Activity Variables.

Table 6 estimation results of specification (7), where the treatment group consists of the USD mandated contracts and the control group of the USD non-mandated contracts. VLM is the amount of gross notional traded in U.S. dollars, NTRADES is the number of trades executed and NPARTIES is the number of unique counterparties active on a given day. DATE<sup>(1)</sup> is a dummy variable that takes the value of 1 after the introduction of SEF trading on Oct. 2, 2013 and DATE<sup>(2)</sup> is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1. MAT is a dummy that takes the value 1 for mandated contracts, and 0 otherwise. SWAP\_RV is the daily maturity/currency-specific realized variance of each swap contract calculated using a 30-day rolling window. VIX and VDAX are the S&P 500 and DAX volatility indices and  $\log R_{\text{SP500}}$  and  $\log R_{\text{DAX}}$  are the daily log returns on the indices themselves. O/N\_SPREAD\_USD and O/N\_SPREAD\_EUR are the differences between the overnight unsecured borrowing rates and the respective central bank rates. SLOPE\_USD and SLOPE\_EUR are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. Standard errors are clustered by maturity. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 6 (continued)

USD mandated vs. USD non-mandated - Activity variables						
	VLM	VLM	NTRADES	NTRADES	NPARTIES	NPARTIES
DATE <sup>(1)</sup>	0.1963 (1.64)	-0.2287 (-1.12)	0.5327 (1.24)	-6.1345*** (-3.05)	-0.5161*** (-3.91)	-1.9857*** (-6.32)
MAT $\times$ DATE <sup>(1)</sup>	1.9100** (2.43)	1.7259** (2.29)	17.6343** (2.61)	15.1957** (2.33)	2.0712*** (3.20)	1.6324** (2.73)
DATE <sup>(2)</sup>	-0.0645 (-0.30)	0.2186 (0.56)	0.2127 (0.41)	-3.4326 (-0.75)	-0.1081 (-0.45)	-0.3922 (-0.83)
MAT $\times$ DATE <sup>(2)</sup>	-0.3813 (-1.05)	-0.5056 (-1.41)	-2.6773 (-1.20)	-3.8244 (-1.69)	0.1072 (0.23)	-0.1751 (-0.41)
SWAP_RV		-225.4282 (-1.55)		-1824.3714 (-1.46)		-548.4686*** (-3.73)
VIX		-0.0023 (-0.06)		0.3802 (0.88)		0.1052 (1.76)
VDAX		0.1501** (2.29)		1.5821* (2.11)		0.1283* (1.79)
$\log R_{\text{SP500}}$		-17.6012** (-2.79)		-123.1580 (-1.65)		-7.8017 (-0.92)
$\log R_{\text{DAX}}$		-5.7087 (-1.23)		-165.8872* (-2.14)		-24.8985*** (-3.55)
SLOPE_USD		2.0095 (1.57)		20.1599 (1.56)		5.0426 (1.55)
SLOPE_EUR		2.0631** (2.97)		32.4400*** (2.99)		3.2482*** (3.52)
O/N_SPREAD_USD		-0.0608 (-0.17)		-0.2133 (-0.05)		1.4658** (2.37)
O/N_SPREAD_EUR		1.4410** (2.54)		3.0573 (0.46)		-0.1475 (-0.21)
CONSTANT	4.6513*** (14.97)	1.2543 (0.69)	62.1412*** (20.93)	47.1781** (2.57)	20.9446*** (62.82)	17.4549*** (7.66)
<i>Within-R</i> <sup>2</sup> <i>N</i>	0.049 5,875	0.061 5,453	0.031 5,875	0.045 5,453	0.013 5,875	0.033 5,453

TABLE 7

Panel Difference-in-Differences Specification for Liquidity Variables Using D2C or D2D Trades.

Table 7 shows estimation results of equation (6), where the treatment group are the USD mandated contracts and the control group are the EUR mandated contracts. The liquidity metrics are defined in equations (1)–(5) but the measures are constructed from either dealer-to-client (first three columns) or dealer-to-dealer (last three columns) trade prices.  $\text{DATE}^{(1)}$  is a dummy variable that takes the value of 1 after the introduction of SEF trading on Oct. 2, 2013 and  $\text{DATE}^{(2)}$  is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1.  $\text{CURR}$  is a dummy that takes the value 1 for USD-denominated contracts, and 0 otherwise.  $\text{SWAP\_RV}$  is the daily maturity/currency-specific variance of each swap contract calculated using a 30-day rolling window.  $\text{VIX}$  and  $\text{VDAX}$  are the S&P 500 and DAX volatility indices and  $\log R_{\text{SP500}}$  and  $\log R_{\text{DAX}}$  are the daily log returns on the indices themselves.  $\text{O/N\_SPREAD\_USD}$  and  $\text{O/N\_SPREAD\_EUR}$  are the differences between the overnight unsecured borrowing rates and the respective central bank rates.  $\text{SLOPE\_USD}$  and  $\text{SLOPE\_EUR}$  are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. The model is estimated using maturity and currency fixed effects. Standard errors are clustered by maturity and currency. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 7 (continued)

USD mandated vs. EUR mandated - Liquidity variables						
	D2C			D2D		
	DISP_VW	DISP_JNS	DISP_BZ	DISP_VW	DISP_JNS	DISP_BZ
DATE <sup>(1)</sup>	-0.1605*** (-5.68)	-0.3344*** (-6.00)	-0.1253*** (-2.94)	-0.2077*** (-6.46)	-0.3253*** (-6.52)	-0.2277*** (-4.75)
CURR $\times$ DATE <sup>(1)</sup>	-0.0370 (-1.18)	0.0392 (0.69)	-0.1066* (-2.00)	0.0002 (0.01)	0.0240 (0.59)	-0.0148 (-0.27)
DATE <sup>(2)</sup>	0.0329 (0.94)	0.0545 (0.89)	0.0777* (1.76)	0.0021 (0.08)	0.0263 (0.50)	0.0521 (1.29)
CURR $\times$ DATE <sup>(2)</sup>	-0.0679* (-1.80)	-0.1264* (-1.96)	-0.1005* (-1.95)	-0.0923** (-2.47)	-0.1441** (-2.29)	-0.1707*** (-3.80)
SWAP_RV	29.2816** (2.37)	52.9601* (2.07)	46.5183*** (4.30)	34.0819* (1.75)	64.3465* (1.89)	36.6113 (1.67)
VIX	0.0121** (2.75)	0.0111** (2.20)	0.0211** (2.13)	0.0083* (1.81)	0.0043 (0.91)	0.0180* (2.07)
VDAX	0.0081 (1.67)	0.0216*** (3.45)	0.0086 (1.00)	0.0124** (2.57)	0.0260*** (4.04)	0.0113 (1.28)
$\log R_{SP500}$	-0.8544 (-0.68)	-1.6085 (-1.53)	-2.3369 (-0.95)	-2.9483*** (-2.93)	-4.1101*** (-3.96)	-4.0304* (-1.81)
$\log R_{DAX}$	-0.2588 (-0.34)	-4.0102** (-2.73)	2.1912* (2.03)	1.4921** (2.18)	-1.5449 (-1.33)	6.3466*** (5.34)
SLOPE_USD	-0.0967** (-2.66)	-0.1177** (-2.77)	-0.1878*** (-2.90)	-0.1337*** (-3.09)	-0.1579** (-2.41)	-0.2190*** (-3.80)
SLOPE_EUR	0.0359 (0.72)	-0.0002 (-0.00)	0.1464* (1.74)	0.0353 (0.52)	0.0196 (0.21)	0.0962 (0.93)
O/N_SPREAD_USD	-0.3949** (-2.81)	0.2389* (1.74)	-1.3315*** (-4.23)	-0.3408 (-1.70)	-0.0427 (-0.18)	-1.0397*** (-2.83)
O/N_SPREAD_EUR	0.2905*** (5.09)	0.5729*** (5.51)	0.2035** (2.31)	0.4028*** (5.89)	0.6490*** (6.16)	0.4054*** (3.90)
CONSTANT	0.6626*** (6.59)	1.1258*** (8.52)	0.6634*** (3.59)	0.8072*** (5.73)	1.2133*** (6.78)	0.9657*** (4.41)
<i>Within-<math>R^2</math></i>	0.050	0.056	0.029	0.068	0.064	0.034
<i>N</i>	8,086	8,086	8,086	8,086	8,086	8,086

TABLE 8

Panel Difference-in-Differences Specification for Liquidity Variables Using D2C or D2D Trades.

Table 8 shows estimation results of equation (6), where the treatment group are the USD mandated contracts and the control group are the USD non-mandated contracts. The liquidity metrics are defined in equations (1)–(5) but the measures are constructed from either dealer-to-client (first three columns) or dealer-to-dealer (last three columns) trade prices.  $\text{DATE}^{(1)}$  is a dummy variable that takes the value of 1 after the introduction of SEF trading on Oct. 2, 2013 and  $\text{DATE}^{(2)}$  is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1.  $\text{MAT}$  is a dummy that takes the value 1 for mandated contracts, and 0 otherwise.  $\text{SWAP\_RV}$  is the daily maturity/currency-specific realized variance of each swap contract calculated using a 30-day rolling window.  $\text{VIX}$  and  $\text{VDAX}$  are the S&P 500 and DAX volatility indices and  $\log R_{\text{SP500}}$  and  $\log R_{\text{DAX}}$  are the daily log returns on the indices themselves.  $\text{O/N\_SPREAD\_USD}$  and  $\text{O/N\_SPREAD\_EUR}$  are the differences between the overnight unsecured borrowing rates and the respective central bank rates.  $\text{SLOPE\_USD}$  and  $\text{SLOPE\_EUR}$  are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. Standard errors are clustered by maturity. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5% and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 8 (continued)

USD mandated vs. USD non-mandated - Liquidity variables						
	D2C			D2D		
	DISP_VW	DISP_JNS	DISP_BZ	DISP_VW	DISP_JNS	DISP_BZ
DATE <sup>(1)</sup>	-0.1757*** (-5.63)	-0.2757*** (-4.40)	-0.1961** (-2.70)	-0.2378*** (-4.58)	-0.3557*** (-10.16)	-0.3111*** (-3.75)
MAT $\times$ DATE <sup>(1)</sup>	0.0134 (0.37)	0.0264 (0.37)	-0.0198 (-0.30)	0.0342 (0.61)	0.0843* (2.14)	0.0338 (0.40)
DATE <sup>(2)</sup>	0.0447 (1.63)	-0.0233 (-0.67)	0.0983* (1.81)	-0.0618* (-2.07)	-0.0448 (-1.03)	-0.0239 (-0.40)
MAT $\times$ DATE <sup>(2)</sup>	-0.0713*** (-4.50)	-0.0393 (-1.59)	-0.1108* (-2.10)	-0.0064 (-0.21)	-0.0402 (-0.82)	-0.0739 (-1.35)
SWAP_RV	7.7447 (1.22)	6.1456 (0.68)	38.8071*** (3.32)	-0.9503 (-0.11)	5.4553 (0.35)	3.1516 (0.20)
VIX	0.0104 (1.67)	0.0090 (1.65)	0.0209 (1.49)	0.0086* (1.80)	0.0045 (0.99)	0.0200* (1.88)
VDAX	0.0176** (2.69)	0.0267*** (4.29)	0.0254* (2.13)	0.0205*** (3.73)	0.0351*** (4.12)	0.0252** (2.24)
$\log R_{SP500}$	-3.7757** (-2.73)	-3.8327* (-2.14)	-7.4619** (-2.24)	-5.4071*** (-4.94)	-4.0018** (-2.20)	-10.6833*** (-4.62)
$\log R_{DAX}$	0.4674 (0.50)	-0.1334 (-0.12)	1.2727 (0.79)	1.4733** (2.73)	-0.3310 (-0.29)	4.8861*** (3.95)
SLOPE_USD	-0.1193*** (-4.15)	-0.1956*** (-5.36)	-0.1436* (-1.86)	-0.2032*** (-5.38)	-0.2575*** (-4.70)	-0.2880*** (-4.11)
SLOPE_EUR	0.0913 (1.69)	0.0726 (1.04)	0.1983* (2.03)	0.1680*** (3.19)	0.1799** (2.87)	0.2756** (2.57)
O/N_SPREAD_USD	-0.2546 (-1.59)	-0.2468 (-1.51)	-0.7301* (-1.98)	-0.0251 (-0.13)	-0.4298 (-1.55)	-0.3192 (-0.85)
O/N_SPREAD_EUR	0.2419*** (3.60)	0.4442*** (4.67)	0.2265* (1.77)	0.4794*** (6.05)	0.5890*** (7.06)	0.6621*** (5.10)
CONSTANT	0.4960*** (3.67)	0.9949*** (4.82)	0.3963 (1.60)	0.6464*** (3.84)	0.9113*** (4.01)	0.8199** (2.89)
<i>Within-R</i> <sup>2</sup>	0.063	0.064	0.047	0.090	0.084	0.057
<i>N</i>	5,329	5,329	5,329	5,329	5,329	5,329

TABLE 9

Liquidity Panel Regressions Utilizing the SEF Variable.

Table 9 shows the estimation results of specification (10) for USD and EUR-denominated mandated contracts and where liquidity variables are the dependent ones. The liquidity metrics are defined in equations (1)–(5). SEF is the percent of the total trading volume executed on a SEF,  $\text{DATE}^{(1)}$  is a dummy variable that takes the value of 1 after the introduction of SEF trading (Oct. 2, 2013),  $\text{SWAP\_RV}$  is the daily maturity/currency-specific realized variance of each swap contract calculated using a 30-day rolling window,  $\text{VIX}$  and  $\text{VDAX}$  are the S&P 500 and DAX volatility indices and  $\log R_{\text{SP500}}$  and  $\log R_{\text{DAX}}$  are the daily log returns on the indices themselves.  $\text{O/N\_SPREAD\_USD}$  and  $\text{O/N\_SPREAD\_EUR}$  are the differences between the overnight unsecured borrowing rates and the respective central bank rates.  $\text{SLOPE\_USD}$  and  $\text{SLOPE\_EUR}$  are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. The model is estimated using maturity and currency fixed effects. We report 2 sets of results: (i) fixed effects specifications (FE) and (ii) instrumental variable fixed effects specifications (FE&IV), where SEF is treated as endogenous and is instrumented using own lags. Standard errors are clustered by maturity and currency. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 9 (continued)

	DISP_VW	DISP_VW	DISP_JNS	DISP_JNS	DISP_BZ	DISP_BZ	QSPREAD	QSPREAD	AMIHU	AMIHU
SEF	-0.1029*** (-3.53)	-0.2905*** (-4.69)	-0.0866* (-2.06)	-0.3367*** (-3.45)	-0.1993*** (-5.24)	-0.4126*** (-3.26)	-0.0011 (-0.64)	-0.0037** (-2.37)	-1.0228*** (-2.85)	-3.2738*** (-7.75)
DATE <sup>(1)</sup>	-0.1668*** (-5.74)	-0.0421 (-1.04)	-0.2689*** (-6.14)	-0.1110* (-1.74)	-0.1584*** (-5.43)	-0.0179 (-0.22)	0.0046** (2.58)	0.0062*** (6.01)	-0.6295 (-1.61)	0.5515** (2.05)
SWAP_RV	36.7326* (2.06)	28.8136*** (5.66)	58.5807* (1.97)	50.1179*** (6.26)	50.8243*** (3.27)	37.2267*** (3.58)	4.2579*** (4.30)	4.1662*** (32.76)	307.1833** (2.19)	216.7732*** (6.45)
VIX	0.0104** (2.61)	0.0091* (1.95)	0.0076 (1.36)	0.0063 (0.86)	0.0248*** (3.74)	0.0240** (2.53)	-0.0004*** (-5.85)	-0.0003*** (-2.92)	0.0788 (1.36)	0.0981*** (3.21)
VDAX	0.0105** (2.53)	0.0126*** (2.66)	0.0226*** (4.00)	0.0232*** (3.11)	0.0069 (0.86)	0.0100 (1.03)	-0.0005* (-1.87)	-0.0005*** (-4.45)	0.0125 (0.18)	0.0018 (0.06)
$\log R_{SP500}$	-2.8081*** (-3.23)	-3.8429*** (-4.38)	-3.6104*** (-3.79)	-5.3726*** (-3.89)	-4.0848* (-1.84)	-6.0128*** (-3.35)	-0.0089* (-2.07)	-0.0163 (-0.74)	5.0503 (1.10)	7.5303 (1.28)
$\log R_{DAX}$	1.5643** (2.45)	1.8304*** (2.96)	-1.6442 (-1.39)	-0.9388 (-0.97)	6.1359*** (5.43)	6.6646*** (5.28)	0.0129** (2.66)	0.0165 (1.06)	2.9507 (0.82)	0.8081 (0.19)
SLOPE_USD	-0.1191*** (-3.59)	-0.1005*** (-3.33)	-0.1434*** (-2.84)	-0.1131** (-2.38)	-0.2154*** (-4.48)	-0.1888*** (-3.06)	-0.0114*** (-5.35)	-0.0113*** (-14.98)	0.5225 (0.79)	0.5694*** (2.87)
SLOPE_EUR	0.0348 (0.68)	0.0242 (0.74)	0.0138 (0.16)	-0.0177 (-0.34)	0.1151 (1.69)	0.1202* (1.79)	-0.0034 (-1.14)	-0.0037*** (-4.54)	-2.7621** (-2.57)	-2.9485*** (-13.72)
O/N_SPREAD_USD	-0.4395** (-2.44)	-0.2934 (-1.45)	-0.1624 (-0.79)	-0.0694 (-0.22)	-1.2867*** (-3.29)	-1.0384** (-2.52)	-0.0010 (-0.42)	0.0017 (0.33)	0.0271 (0.03)	1.5344 (1.16)
O/N_SPREAD_EUR	0.3808*** (6.39)	0.3620*** (6.67)	0.5816*** (5.90)	0.5575*** (6.53)	0.4126*** (5.18)	0.3934*** (3.55)	0.0093*** (3.51)	0.0097*** (7.07)	-1.4174** (-2.52)	-0.9933*** (-2.82)
CONSTANT	0.8235*** (7.04)	0.7988*** (9.47)	1.1915*** (6.63)	1.1929*** (8.99)	1.0237*** (5.62)	0.9509*** (5.52)	0.0684*** (5.85)	0.0692*** (32.78)	10.5183*** (7.82)	10.8236*** (19.72)
<i>Within-R<sup>2</sup></i>	0.0786	0.0687	0.0664	0.0591	0.0438	0.0415	0.2956	0.2882	0.1281	0.0953
<i>N</i>	7795	7074	7795	7074	7795	7074	7663	6947	7387	6714
<i>Specification</i>	FE	FE&IV	FE	FE&IV	FE	FE&IV	FE	FE&IV	FE	FE&IV



TABLE 10

Activity Panel Regressions Utilizing the SEF Variable.

Table 10 shows the estimation results of specification (10) for USD and EUR-denominated mandated contracts and where activity variables are the dependent ones. VLM is the amount of gross notional traded in U.S. dollars, NTRADES is the number of trades executed and NPARTIES is the number of unique counterparties active on a given day. SEF is the percent of the total trading volume executed on a SEF, DATE<sup>(1)</sup> is a dummy variable that takes the value of 1 after the introduction of SEF trading (Oct. 2, 2013), SWAP\_RV is the daily maturity/currency-specific realized variance of each swap contract calculated using a 30-day rolling window, VIX and VDAX are the S&P 500 and DAX volatility indices and  $\log R_{SP500}$  and  $\log R_{DAX}$  are the daily log returns on the indices themselves. O/N\_SPREAD\_USD and O/N\_SPREAD\_EUR are the differences between the overnight unsecured borrowing rates and the respective central bank rates. SLOPE\_USD and SLOPE\_EUR are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. The model is estimated using maturity and currency fixed effects. We report 2 sets of results: (i) fixed effects specifications (FE) and (ii) instrumental variable fixed effects specifications (FE&IV), where SEF is treated as endogenous and is instrumented using own lags. Standard errors are clustered by maturity and currency. Robust *t*-statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 10 (continued)

	VLM	VLM	NTRADES	NTRADES	NPARTIES	NPARTIES
SEF	1.0991** (2.39)	3.5368*** (6.00)	12.5107** (2.46)	36.0019*** (5.92)	1.1922** (2.37)	1.0802 (1.20)
DATE <sup>(1)</sup>	-0.1474 (-0.83)	-1.5360*** (-3.98)	-6.6839** (-2.55)	-20.3018*** (-5.11)	-0.9629** (-2.69)	-0.8962 (-1.52)
SWAP_RV	-23.0222 (-0.20)	52.3171 (1.08)	-486.6971 (-0.51)	186.9327 (0.37)	-159.5672 (-0.83)	-193.2745*** (-2.61)
VIX	-0.0002 (-0.01)	-0.0135 (-0.31)	0.6743* (1.94)	0.4919 (1.08)	0.0693 (1.22)	0.0403 (0.60)
VDAX	0.1266*** (3.52)	0.1226*** (2.71)	1.1320*** (2.92)	1.0597** (2.27)	0.2241*** (3.53)	0.2593*** (3.76)
log $R_{SP500}$	-6.3167 (-1.32)	-16.0204* (-1.92)	-30.8376 (-0.61)	-134.0619 (-1.55)	2.0093 (0.30)	-6.4599 (-0.51)
log $R_{DAX}$	-3.3225 (-0.76)	-2.2498 (-0.38)	-116.5080* (-1.92)	-99.9945* (-1.65)	-9.8547 (-1.35)	-9.5957 (-1.07)
SLOPE_USD	-0.6096 (-1.35)	-0.6815** (-2.37)	-7.0445* (-1.73)	-9.0652*** (-3.06)	0.3229 (0.47)	0.5465 (1.25)
SLOPE_EUR	1.9408*** (3.81)	2.4542*** (7.84)	14.4390*** (3.15)	20.5942*** (6.38)	1.2597 (1.58)	1.2872*** (2.70)
O/N_SPREAD_USD	-0.8207 (-0.69)	0.3127 (0.16)	-2.2228 (-0.19)	3.8232 (0.19)	-0.5797 (-0.19)	2.1097 (0.72)
O/N_SPREAD_EUR	2.1873*** (3.88)	2.4904*** (4.82)	27.8625*** (3.85)	32.3748*** (6.08)	2.9634*** (3.40)	3.1571*** (4.01)
CONSTANT	2.5937* (1.90)	2.2338*** (2.78)	42.7607*** (3.37)	42.8665*** (5.18)	17.7379*** (12.67)	17.7182*** (14.47)
<i>Within-R<sup>2</sup></i>	0.0273	0.0122	0.0272	0.0151	0.0237	0.0256
<i>N</i>	7795	7074	7795	7074	7795	7074
<i>Specification</i>	FE	IV&FE	FE	IV&FE	FE	IV&FE

TABLE 11

Difference-in-Differences Regressions of the Number of Unique Dealers per Client.

Table 11 shows the estimation results of model (11).  $NDEALERS_{it}$  is the number of unique dealers with whom client  $i$  trades in month  $t$ .  $DATE_t^{(1)}$  is a dummy variable that takes the value of 1 after the introduction of SEF trading (Oct. 2, 2013) and  $DATE_t^{(2)}$  is the Feb. 2014 mandated trading dummy.  $U\_S_i$  is a dummy for clients that are U.S. legal entities and  $ACTIVE_i$  is a dummy for clients who trade more than 20 times a month (on average).  $VLM_{it}$ ,  $NTRADES_{it}$  and  $NCONTRACTS_{it}$  are the volume traded (in £billions), the number of trades executed and the number of different contracts traded respectively by client  $i$  in month  $t$ . The model is estimated using client ID fixed effects. Standard errors are clustered by client ID. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 11 (continued)

	NDEALERS	NDEALERS
DATE <sup>(1)</sup>	0.3557* (1.94)	0.1572 (1.04)
DATE <sup>(2)</sup>	-0.0161 (-0.06)	0.0965 (0.46)
U_S×DATE <sup>(1)</sup>	0.1904 (0.59)	0.1875 (0.68)
U_S×DATE <sup>(2)</sup>	-0.6695 (-1.44)	-0.7345* (-1.92)
ACTIVE	3.6733*** (8.28)	1.9699*** (5.85)
DATE <sup>(1)</sup> ×ACTIVE	-0.0479 (-0.18)	0.3396 (1.58)
DATE <sup>(2)</sup> ×ACTIVE	0.0066 (0.02)	-0.2495 (-0.74)
U_S×ACTIVE	0.6325 (0.95)	0.6239 (1.17)
U_S×DATE <sup>(1)</sup> ×ACTIVE	-0.3178 (-0.59)	-0.2169 (-0.49)
U_S×DATE <sup>(2)</sup> ×ACTIVE	1.5754*** (2.62)	1.8168*** (3.29)
NTRADES		0.0064*** (5.83)
VLM		0.2022 (0.25)
NCONTRACTS		0.4966*** (14.94)
CONSTANT	5.3342*** (37.99)	2.7448*** (13.32)
Fixed Effects	Yes	Yes
<i>Within-R</i> <sup>2</sup>	0.280	0.472
<i>N</i>	2633	2633

TABLE 12

Time Series Regressions of the Percentage of U.S.-to-non-U.S. Volume.

Table 12 shows the estimation results of time series regressions of the percentage of U.S.-to-non-U.S. volume in the USD and EUR-denominated contracts.  $DATE^{(1)}$  is a time dummy that takes the value 1 after the introduction of SEF trading on Oct. 2, 2013,  $AVG\_SWAP\_RV$  is the daily cross-maturity average currency-specific swap realized variance calculated using a 30-day rolling window,  $\log R_{SP500}$  and  $\log R_{DAX}$  are the daily log returns of the S&P 500 and DAX indices and  $VIX$  and  $VDAX$  are estimates of the implied volatility of these indices.  $O/N\_SPREAD\_USD$  and  $O/N\_SPREAD\_EUR$  are the differences between the overnight unsecured borrowing rates and the respective central bank rates.  $SLOPE\_USD$  and  $SLOPE\_EUR$  are the spreads between the 10-year and 3-month government securities of the United States and the investment grade Eurozone countries respectively. Robust  $t$ -statistics are shown in the parentheses. \*, \*\*, and \*\*\* indicate significance at the 10%, 5%, and 1% levels, respectively. The time period is Jan. 1, 2013 to Sept. 15, 2014.

TABLE 12 (continued)

	U.S.-to-non U.S., % (USD)	U.S.-to-non U.S., % (EUR - All)	U.S.-to-non U.S., % (EUR - D2D)	U.S.-to-non U.S., % (EUR - D2C & C2C)
DATE <sup>(1)</sup>	0.0140 (0.89)	-0.1685*** (-9.40)	-0.1669*** (-9.47)	-0.0009 (-0.13)
AVG_SWAP_RV	-19.1248 (-0.89)	-3.0357 (-0.46)	-9.2632* (-1.78)	6.3420 (1.33)
VIX	0.0002 (0.08)	0.0011 (0.36)	0.0037 (1.30)	-0.0027* (-1.88)
VDAX	0.0043 (1.40)	-0.0017 (-0.51)	-0.0050 (-1.56)	0.0036** (2.28)
$\log R_{SP500}$	-0.4936 (-0.78)	0.5239 (0.84)	0.7324 (1.27)	-0.2146 (-0.79)
$\log R_{DAX}$	0.1700 (0.37)	-0.3264 (-0.82)	-0.1077 (-0.29)	-0.2103 (-1.27)
SLOPE_USD	-0.0052 (-0.16)	0.0059 (0.22)	0.0367 (1.50)	-0.0308** (-2.41)
SLOPE_EUR	0.0245 (0.76)	0.0251 (1.08)	0.0028 (0.13)	0.0226* (1.86)
O/N_SPREAD_USD	0.1027 (0.52)	-0.2739 (-1.41)	-0.2029 (-1.34)	-0.0709 (-0.67)
O/N_SPREAD_EUR	-0.0764 (-1.63)	-0.0609 (-1.62)	-0.0728** (-2.35)	0.0106 (0.56)
CONSTANT	0.3749*** (5.60)	0.1589*** (2.61)	0.1078* (1.88)	0.0469 (1.47)
$R^2$	0.080	0.744	0.745	0.153
$N$	285	285	285	285